HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 57

EDIBLE CANNA IN THE WAIMEA DISTRICT OF HAWAII

BY

J. C. RIPPERTON, Chemist

and

R. A. GOFF, Extension Agent for the Island of Hawaii

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[1] Appointed December 3, 1925.

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CONTENTS

INTRODUCTION

The farmers of Hawaii have at different times attempted to produce starch from the root crops of cassava, sweet potatoes, and taro. None of these attempts, however, proceeded any further than to meet the needs of a small local demand. Tree-fern starch was manufactured on a small scale on the island of Hawaii in 1920, but the industry was abandoned two years later because of the high cost of securing the raw material from the forests and the very slow rate of growth of the trees, which makes it impracticable to replant cut-over areas (*8, pp. 7–9*).[1]

The remarkable growth of small plantings of edible canna (*Canna edulis*) at Waimea, Hawaii, led to a fertilizer experiment with the crop in the Homestead tract in that region in 1923. Since then experiments totaling 15 acres have been carried on in cooperation with a private starch-manufacturing concern. The homesteaders of the district have shown considerable interest in the development of the edible canna, devoting approximately 125 acres to their first crop.[2] A starch mill was erected at Waimea in October, 1925, manu-

[1] Reference is made by numbers (italic) to "Literature cited." p. 41.

[2] The writers wish to thank the Waimea Starch Co. for its generous cooperation and help in making possible the experiments reported upon.

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facture of the commercial product was begun in March, 1926, and the starch appeared on the local markets shortly afterwards.

The data presented in this bulletin represent largely the results of field experiments with edible canna at Waimea.

THE WAIMEA DISTRICT

The Waimea district (fig. 1), comprising an area of approximately 15 miles square, is a slightly rolling table-land lying 2,600 to 2,700 feet above sea level. The plateau is volcanic in origin, the surface being a mixture of disintegrated lava, pumice, and ash. The ash extends to a depth of 2 to 3 feet in some places, and small outcroppings of partially intact lava flows occur in others. That part of the district in which the Homestead tract is located is the only part devoted

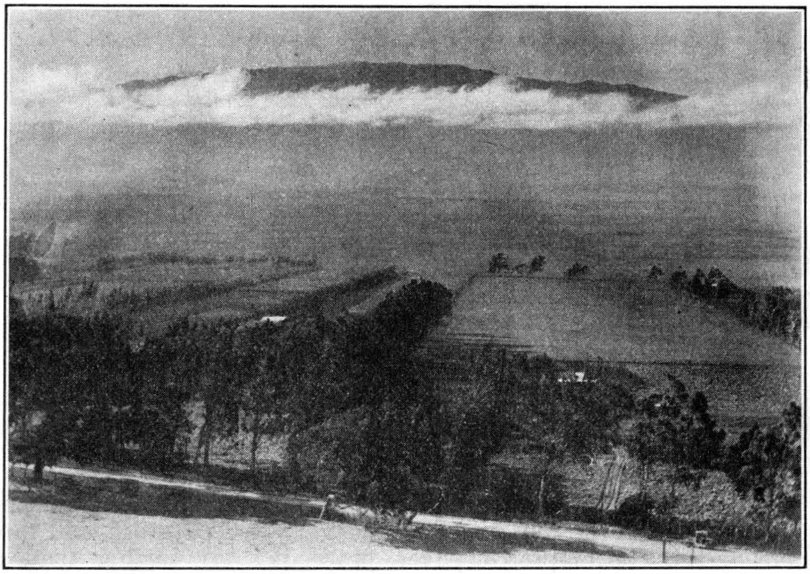

FIG. 1.—General view of the Waimea district. Foreground, a section of the homesteads; background, Mauna Kea

to agriculture at present, lies close to the foothills of the Kohala Range, and is overlain to some extent by the wash from the mountains. The growth of the dense forest which covered the plains 40 or 50 years ago is said to have been destroyed by fires and cattle, and the light, fluffy surface soil to have been carried by the constantly recurring strong winds from the plains to the lee of the Kohala Mountains in the Kawaihae district. This fact probably accounts for the poor growth made in the central part of the plains by range grasses which grow luxuriantly at the base of the mountains.

CLIMATE

The climate of the Waimea district is influenced by its location between two comparatively high mountains. The height of Mauna Kea (13,825 feet) deflects the normal northeast trade winds along the lower Hamakua district toward the Waimea pass, where, at

Ookala, the wind is from the southeast. As a result, the wind increases considerably in velocity through Waimea.

Occasionally the prevailing trade winds are supplanted by Kona (south) winds. These usually give rise to unsettled weather with strong winds and are regarded as deleterious both to health and to crop growth.

Table 1 compares the climatological data of Waimea and other districts.

TABLE 1.—*Comparison of climatological data of Waimea and other districts* [1]

Locality	Length of record	Altitude	Temperature					Number of cloudy days [2]	Annual precipitation
			Maximum	Minimum	Mean maximum	Mean minimum	Annual mean		
	Years	*Feet*	°*F*	°*F*	°*F*	°*F*	°*F*		*Inches*
Waimea	11	2,700	83	34	69.8	55.4	62.9	231	43.50
Ookala	13	400	88	53	79.0	64.7	71.9	220	118.00
Honokaa	11	1,042	91	53	79.3	63.7	71.5	184	72.98
Ahualoa homesteads	7	2,551							117.53
Puuhinei Paddock		1,500							19.00

[1] Taken from the monthly publication Climatological Data, Hawaiian Section, U. S. Dept. Agr. Weather Bur. (*12*).
[2] 0.01 inch of rain or more.

The rainfall is copious on the rising slope of practically all the Hamakua district, but decreases rapidly toward the west on the comparatively level plains of Waimea. In progressing from Ookala (400 feet) to Ahualoa homesteads (2,551 feet) the rainfall remains practically constant, 118 inches of rain falling at the former place, and 117 inches at the latter place. From Ahualoa homesteads to Waimea, a distance of approximately 10 miles, the elevation increases only 159 feet, whereas the annual rainfall decreases to 43 inches. At Puuhinei Paddock (1,500 feet), about 10 miles west of Waimea, the rainfall is only 19 inches.

Notwithstanding the lower annual rainfall, the Waimea district gives the appearance of being as well watered as are the lower levels where the precipitation is several times as heavy. As is shown by the table, Waimea exceeds the lower levels in number of cloudy days; that is, days during which 0.01 inch or more of rain falls. With the temperature so frequently at the dew point, heavy dews and almost daily fogs occur, and the rate of evaporation is of course comparatively small. These factors, together with the loose soil and comparatively level topography which prevents losses by run-offs, make possible the maximum utilization of the rainfall by the crops.

The table shows that Waimea has a mean temperature of about 9° F. less than the lower windward levels. The range from the mean maximum to the mean minimum is the same, being 14.3° F. at Ookala and 14.4° F. at Waimea. The extreme range over a period of 13 years at Ookala was 35° F. and at Waimea 49° F. The lowest recorded temperature at Waimea was 34° F.

In Table 2 are given the monthly and annual precipitation for the years 1919–1926, and a summary of the average monthly precipitation for the years 1891–1918.

TABLE 2.—*Monthly and annual precipitation at Waimea for the calendar years 1919–1926,*[1] *and summary of the average monthly rainfall for the period 1891–1918* [2 3]

Month	1919	1920	1921	1922	1923	1924	1925	1926	Average, 1891–1918
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	3.25	7.06	6.63	6.61	12.60	1.85	2.86	1.84	4.76
February	1.59	1.55	.65	8.91	2.79	3.60	1.35	2.31	4.64
March	2.86	3.15	3.51	9.06	8.43	2.34	7.39	1.18	4.98
April	2.79	2.98	3.73	3.05	8.96	4.46	6.44	3.06	3.66
May	1.89	1.22	1.78	1.47	2.26	1.60	2.80	3.62	3.14
June	2.85	1.20	.93	2.37	2.87	.58	3.94	1.77	2.45
July	3.18	2.26	4.07	2.27	3.70	2.82	2.11	4.07	2.89
August	3.06	2.71	2.44	4.75	3.49	1.55	4.00		3.25
September	2.04	2.27	2.60	5.09	2.32	.98	2.23		2.19
October	.24	1.34	1.68	2.67	3.29	6.14	3.04		2.61
November	.64	3.79	12.98	2.86	2.49	8.95	2.07		3.52
December	4.78	6.51	5.14	.93	9.06	3.40	2.20		5.41
Total	29.17	36.04	46.14	50.04	62.26	38.27	40.43		43.50
Departure from normal	−14.33	−7.46	+2.64	+6.54	+18.75	−5.23	−3.07		
Number of rainy days [4]	246	223	266	282	293	274	265		231

[1] (*11*).
[2] The data in Tables 1 and 2 were obtained from the United States Weather Bureau Station, located at lot No. 52 of the first series of homesteads. This is 2½ miles west of the experimental plat and would be somewhat drier than at the plats, since the rainfall decreases toward the west.
[3] (*12*).
[4] 0.01 inch of rain or more.

While the rainfall in a single year is often subject to wide variation from month to month, the average from 1891 to 1918 shows a fairly uniform distribution throughout the year. The heaviest rainfall for the period 1891–1918 occurred during December, January, February, and March. In these four months occurs nearly half the rainfall of the year. During the remaining eight months the maximum variation is 2.19 to 3.66 inches per month. The June and October minima, which are characteristic of Hawaiian climate (*2*), are apparent but somewhat less pronounced than in most other localities. The monthly rainfall for the period 1919–1926 shows large deviations from the normal, but no greater comparatively than occur at the lower levels. Moreover, subnormal annual rainfall often is the result of small precipitation during the winter months and little depression during the drier summer months.

In Table 3 is given the average monthly temperature at Waimea for the calendar years 1919-1926, and a summary of the average monthly temperature for the period 1908-1918.

TABLE 3.—*Average monthly temperature at Waimea for the calendar years 1919–1926* [1] *and a summary of the average monthly temperature for the period 1908–1918* [2]

Month	1919	1920	1921	1922	1923	1924	1925	1926	Average, 1908–1918
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
January	58.6	62.1	59.5	59.9	60.1	61.3	61.4	63.5	61.1
February	60.6	60.4	63.2	57.7	62.7	62.0	62.8	63.6	60.6
March	60.8	60.7	62.1	59.8	61.4	60.8	61.2	63.1	61.2
April	62.4	61.4	60.8	61.4	62.5	64.4	58.8	62.0	61.8
May	62.8	66.4	65.4	61.8	63.0	64.4	61.0	64.0	63.1
June	65.6	65.0	63.8	64.0	63.3	64.9	62.2	68.7	63.2
July	63.8	65.2	63.4	64.0	64.1	64.6	65.2	66.8	64.0
August	64.8	64.9	64.0	64.2	66.4	64.4	64.5		64.9
September	66.0	64.3	62.8	64.4	66.5	65.3	65.8		65.3
October	65.6	64.0	65.0	65.4	66.2	64.6	64.7		64.9
November	65.1	62.2	63.0	62.7	63.3	64.8	65.0		63.3
December	64.2	61.1	60.9	62.6	61.2	63.2			61.2
Average	63.4	63.1	62.8	62.3	63.4	63.7			62.9
Departure from normal	+0.5	+0.2	−0.1	−0.6	+0.5	+0.8			

[1] (*11*). [2] (*12*).

Table 3 shows that the Waimea district has the same uniformity of temperature throughout the year that is characteristic of the Hawaiian Islands as a whole. The 10-year average for February, the coldest month, was but 4.7° F. less than that for September, the warmest month. The greatest annual departure from the normal was 0.8° F.

SOILS

The soils of the Waimea district, being of a porous nature, offer striking contrast to the exceedingly heavy soils of the majority of the lower lying sugar-cane and pineapple lands of the islands (*5, p. 33–35*). Mechanical analyses of the heavy types show a clay content ranging usually from 10 to as high as 58 per cent and correspondingly high amounts of fine silt and silt fractions, but negligible amounts of coarse sand or fine gravel. The heavy soils pack with rocklike hardness, can be plowed only with difficulty, and puddle if plowed or cultivated when they are too wet. In the Waimea district the soils are light, fluffy, and deep and can be easily plowed with an ordinary moldboard plow and light team. Such soils show little tendency to pack and do not puddle when worked during wet weather.

Table 4 gives the analyses of soils of the Waimea district.

TABLE 4.—*Analyses of soils of the Waimea-Puukapu, Waikii, and Makahalau sections*

Constituent	Waimea-Puukapu section; soil No. 474	Waikii section;[1] soil No. 76	Makahalau section;[1] soil No. 468
	Per cent	*Per cent*	*Per cent*
Water	[2] 13.59	[2] 33.85	[2] 11.52
Volatile matter	20.01	11.79	18.92
Insoluble residue	33.77	32.17	44.06
Ferric oxide (Fe_2O_3)	7.00	8.36	8.80
Alumina (Al_2O_3)	16.79	11.25	8.93
Titanium oxide (TiO_2)	1.80	----------	2.00
Manganese oxide (Mn_3O_4)	.07	.02	.14
Lime (CaO)	3.80	1.54	2.32
Magnesia (MgO)	.85	.87	1.42
Potash (K_2O)	.72	.13	.22
Soda (Na_2O)	.10	.28	.33
Phosphoric acid (P_2O_5)	2.18	.17	.86
Sulphur trioxide (SO_3)	.45	.18	.36
Nitrogen (N)	.65	.18	.64
Clay	[3] 5.24	[4] 3.55	----------
Fine silt	24.20	24.45	----------
Silt	18.00	22.90	----------
Fine sand	30.70	26.70	----------
Coarse sand	3.43	2.14	----------
Fine gravel		.02	----------

[1] Waikii and Makahalau are located on the slopes of Mauna Kea, approximately 10 miles across the plains from the Homestead tract. Because of their altitudes (3,500 to 4,500 feet) they are subject to killing frosts in the winter. The analyses of the soils of these two districts are given because of the similarity in origin with those of Waimea proper where canna is being grown.

[2] (*5, p. 20*). [3] (*7, p. 6*). [4] (*5, p. 33*).

Table 4 shows that the soil of the Homestead tract and Waikii district is rather low in clay, a large portion of the soil being distributed between the fine-silt, silt, and fine-sand fractions.

In a comparison of the physical properties of a number of soil types of Hawaii, McGeorge (*6*) found that the Waimea soils have the lowest real and apparent specific gravity, the greatest capillary rise, are among the lowest in rate of percolation, and require the highest percentage of water to fill the interstitial spaces.

In chemical composition (Table 4) the soils of the district differ markedly from most of the other soils of the islands. They are lower in iron, unusually high in lime, and generally high in phosphoric acid. Soil No. 474 from the Homestead tract is well supplied with potash also. Soil No. 76 from Waikii is low in potash, phosphoric acid, and nitrogen, yet it is said to produce excellent crops.

The differences between the soils of Waimea and the heavy types of the islands can be attributed largely to their origin and location. The heavy soils are largely the decomposition products of lava flows, partly residual and partly sedimentary, resulting from erosion of higher areas. The properties of the soils of Waimea are due to the surface deposits of volcanic ash and dust. Moreover, since the annual precipitation at Waimea is much less than at the lower levels the soil has been less subjected to excessive leaching and erosion, as is indicated by its comparatively high content of lime. The loose, deep soil permits ample root development and greatly aids the growth of a crop. Probably the plant-food elements which are tenaciously held by the heavy soils are readily available in the light soils, as is shown in the excellent fertility of soil No. 76, which is very low in potash, phosphoric acid, and nitrogen.

Mechanical and chemical analyses of the soils of the Waimea district are too few to justify specific conclusions concerning the fertility of the soils as a whole. No general survey has been made, and estimates of the fertility of the uncultivated areas must be based largely on the range grasses growing on them. Present indications are that the soils of nearly all the homesteads and a large portion of the adjoining Government lands of the Puukapu district are adapted to edible canna.

AGRICULTURAL RETROSPECT

The first series of homesteads included lots Nos. 1 to 84, with an average of 10 acres per homestead, and was opened in 1897. The second series included lots Nos. 85 to 141, with an average of 40 acres per homestead, and was opened in 1913. This area extends from the village of Kamuela eastward along the foothills of the Kohala Range, and comprises some of the best land in the district.

The district was thought promising as an agricultural center because of the high fertility of its soil and the variety of crops doing well there. Many kinds of vegetables, especially potatoes and cabbage, were apparently well adapted to the region. Of the field crops, corn did exceptionally well, yielding 3,000 to 4,000 pounds per acre. Livestock thrived and with a plentiful supply of corn and nutritious pasturage for feeding formed the nucleus of a well-established diversified agriculture. Later, however, it was found that protracted periods of cold, wet weather, and strong winds, prevented the corn from maturing, and that blight attacked the potato crop. High freight rates and the long haul to the Honolulu market prevented vegetable growing from becoming an economic success.

Wheat was next tried but, like corn, could not be depended upon to mature. Alfalfa made slow growth and required constant care and cultivation to keep down weeds. Finally, the high cost of importing grains and concentrated feeds prohibited the profitable raising of pigs and poultry. Although some Japanese truck gardeners are still raising cabbage and potatoes for market, and in places corn is grown as a feed, and small gardens are maintained to supply the family with sufficient vegetables, a large part of the good land has been turned back to pasture, and agriculture in the district is at a low ebb. What Waimea needs is a stable field crop which can be grown throughout the year and readily converted into cash. Edible canna would seem to meet this need provided the crop can be utilized as a commercial source of starch.

ADAPTATION OF EDIBLE CANNA TO WAIMEA

Of all the places in Hawaii where edible canna has been observed, Waimea seems to be the most nearly ideal for the crop. Observations on small plantings showed that while the crop yielded as well as other starch crops at the lower levels, it made outstandingly high yields only at the higher altitudes. Dry, windy areas caused the succulent tops to shrivel prematurely, and alternately wet and dry conditions resulted in stunted stalks and rootstocks. Under conditions of excessive moisture the crop produced vigorous top growth, but stunted rootstocks. At Waimea growth proceeds notwithstanding such adverse conditions as high winds and protracted periods of cool, cloudy weather which seriously affect other crops, and the plant becomes luxuriant with the return of favorable conditions. The stalk grows 12 feet high at Waimea, whereas it seldom exceeds 6 or 8 feet in most other places. The stem is proportionately greater in diameter at Waimea, and the rootstock greatly surpasses in size and yield any grown at the lower levels.

In a recent publication (*9*) the top growth of edible canna was shown to live longer at Waimea than at the central station in Honolulu. The vigor and longevity of the maximum period of activity of the mature top is thought to be one of the chief causes of the increased growth made by the plant at Waimea. The temperature, dews, mists, and light rains of the region are especially favorable to the crop. The ill effects of strong winds—probably the only serious drawback to the crop—can be overcome by growing windbreaks. Edible canna is adapted to small-farming methods, and weeding and cultivating—the greatest single expenses in growing the crop—can be done by members of the family of the grower. No elaborate machinery is required either for preparing the land or for planting and cultivating the crop.

FIELD PRACTICES

Edible canna has not been grown at Waimea sufficiently long to warrant definite conclusions as to the best agricultural practices with the crop. Climatic and soil conditions are such as to make possible the planting of corn and potatoes every month of the year, although February and August are regarded as the most favorable months for planting. Edible canna plantings of different seasons have shown no outstanding differences in growth. The scheme of continuous planting and harvesting has its advantages since it permits the most economical utilization of labor and equipment during the entire process of field production and manufacture of starch. Before such a plan is established on a large scale, however, experiments should be made to determine the correlation of season of planting to yields.

When the crop is to be grown on land that has been in pasture the heavy sod should be broken. The general practice is to plow to a depth of 6 or 7 inches, then work the soil down with a disk harrow, and allow it to stand until the sod begins to rot and new shoots appear.

A second plowing is then made, followed by harrowing, and in another month by a third plowing and harrowing. The operation is repeated a fourth time if weeds and grass roots have not been wholly destroyed. Although such preparation covers three or four months' work, any attempt to curtail it usually results in depressed yields and increased costs in cultivating after the crop is planted. Cultivated land requires usually only one plowing and disking, and one crop closely follows another. The light soils may be plowed immediately after a heavy rain to facilitate rotting of the weeds and grass.

Continuous cultivation should be given the crop until it attains sufficient size to shade out weed growth. (Fig. 2.) One hoeing is usually enough when the field is check planted, permitting cross cultivation. The importance of clean culture in the early stages of growth of edible canna was strikingly demonstrated in a portion of the experimental

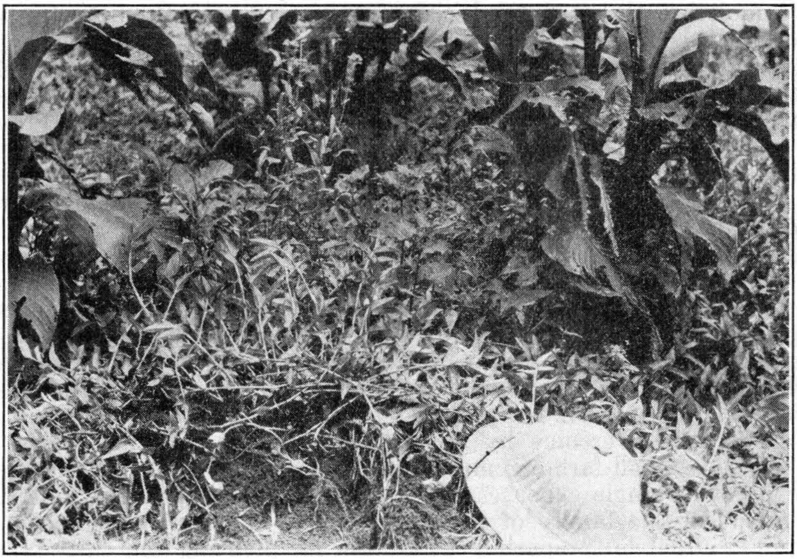

FIG. 2.—A two-month weed growth in a field of canna

plat where weeds were let grow for the first seven months. Although this portion was subsequently weeded and given the same treatment accorded the rest of the plat, it yielded 20 tons less per acre at 20 months than was obtained from the cultivated portion. Animal-drawn cultivators equipped with five shovels are the most commonly used types, although the seven-tooth type is being introduced. With the latter equipment shallower cultivation is possible, the long matted grasses are more readily loosened, and the shallow root growth of the canna plant is less likely to be disturbed.

The expensive process of hand weeding might well be dispensed with in favor of sodium-arsenate spray, which has been used most effectively in the Hamakua and Hilo districts. At Waimea the effectiveness of the spray might be lessened somewhat by the frequent mists and strong winds. The spray as used in the Hamakua and Hilo districts is made as follows (*10, p. 54*).

Boil 2 pounds of white arsenic and 0.42 pound of caustic soda in water until the solution becomes clear. This is made up to 1 gallon with water. For the succulent plants like honohono, dilute to 25 gallons, and for grasses such as Panicum, dilute to 10 gallons. Soap added at the rate of 1 pound per 100 gallons of spray increases the effectiveness of the spray.

Poison bait should be used to control cutworms which attack young fields of canna during the late spring and early summer. A number of formulas suitable for the purpose have been published by the station (*1, p. 7*).

WINDBREAKS

During the greater part of the year the Waimea district is swept by high winds which shred the leaves of the canna plant, draw moisture from the soil, and otherwise prevent normal growth. Crops which are protected by windbreaks make more vigorous and thrifty growth than do those left exposed in the open.

Trees and plants which are used for windbreaks in the Waimea district include eucalyptus (fig. 3), black wattle, Monterey cypress

FIG. 3.—Eucalyptus windbreak, showing paucity of foliage near the base

(fig. 4), castor-bean trees (fig. 5), and the banana plant, and combinations of these. The eucalyptus is quick growing, attains sufficient height in three or four years to protect a field, and has the additional value of supplying fairly good fence posts and firewood when the trees are thinned out or pruned. The black wattle also is quick growing and furnishes more durable posts than the eucalyptus, but bends with the wind to such an extent as to utilize too much ground. The Monterey cypress requires 10 to 12 years to attain a height sufficient to protect a field, but makes an ideal windbreak when it is planted in combination with eucalyptus or black wattle. The Monterey cypress makes straight growth, attains good height, and covers comparatively little area. The lower branches of the eucalyptus die when the tree is about 15 feet high, and the spaces left by these should be filled by the slow-growing cypress. After 10 or 12 years, when the faster growing trees are removed for fence posts or firewood, the cypress can carry on alone. (Fig. 6.) Any variety of banana plant which does not grow over 8 feet high can be planted midway between the more permanent windbreaks to protect a field. The banana plant makes short, compact growth and is of additional value in producing fruit. Castor-bean trees afford protection in less time than any of the other trees now used for windbreaks. They protect a greater area than

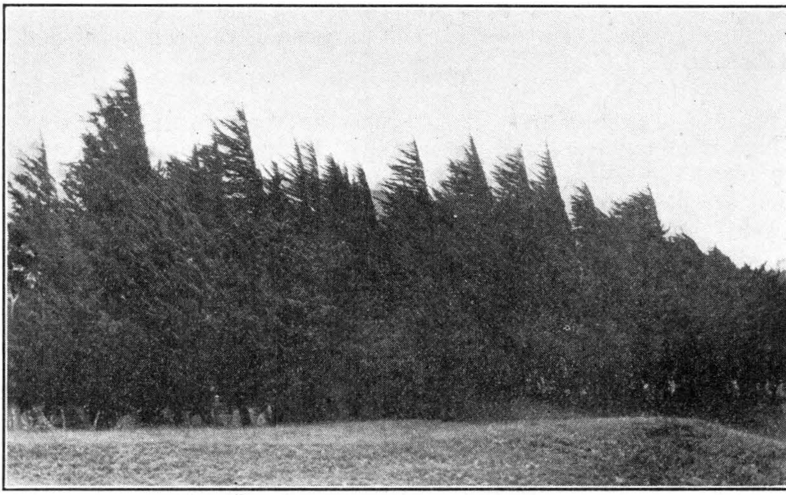

FIG. 4.—An old Monterey cypress windbreak. Note the low-branching and dense foliage; also the lack of top branches on the windward side. The fog shown in the center of the picture is characteristic of Waimea

does the banana plant but less than the eucalyptus-cypress combination, and like the banana are usually planted midway between the more permanent windbreaks at the edges of the field. Probably the best windbreak for the Waimea district is one consisting of a row of

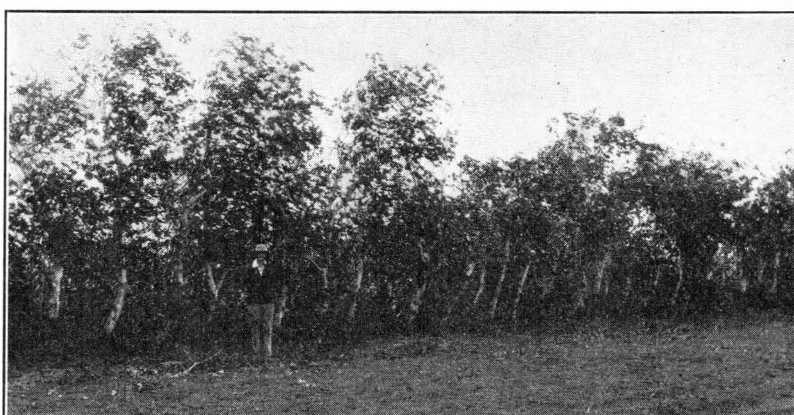

FIG. 5.—A castor-bean windbreak. Note the low, dense growth which makes the tree desirable for secondary windbreaks

Monterey cypress planted close to the fence on the windward side of the field, to the lee of which are two or three rows of eucalyptus. The cypress should be planted 10 feet apart and the eucalyptus 10 feet apart. If further protection is necessary the windbreak across the middle of the field should consist of castor-bean trees or banana plants.

EXPERIMENTS WITH EDIBLE CANNA

Experiments were made to determine the best types of rootstocks to use for planting, the effect of preliminary treatment to prevent rotting of the seed, the depth of planting, the number of seed to plant per hill, the feasibility of mulching with canna tops, the time of applying fertilizer, and the best age at which to harvest the crop. The crop occupied 34 plats, comprising a total of 4.8 acres of land.

The experiments were begun in July, 1924, on homestead No. 98, where the soil is deep, porous, and representative of the best in Waimea. A good windbreak protects the crop from the trade winds. The field was inspected September 4, and the percentage of nongermination was determined for each plat. The misses were replaced in all instances except on the plats used for rootstock-selection tests, for which acre yields were computed from the actual

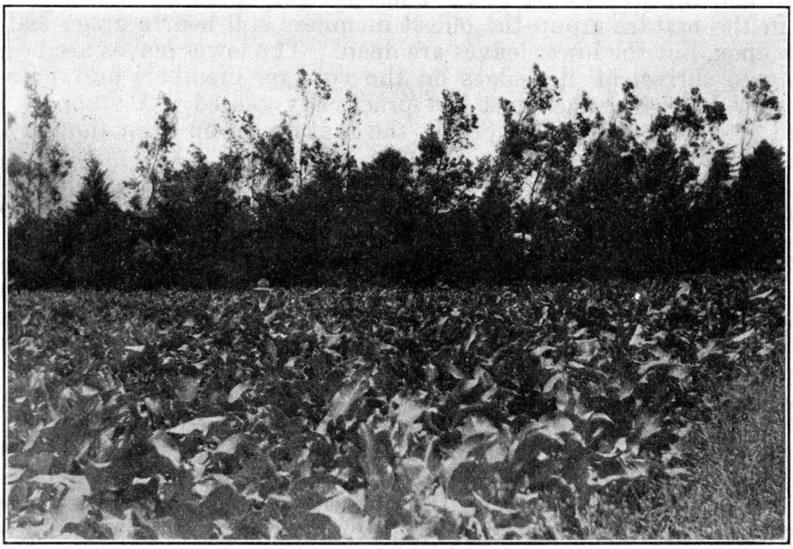

FIG. 6.—Combination windbreak of eucalyptus and Monterey cypress. The cypress is sufficiently high to permit removal of the eucalyptus

number of hills dug. The crop was harvested between March 22 and March 30, 1926, 20.5 months after planting. Visits were made to the plats at intervals of two months, notes were taken on general growth, and some individual hills were dug to study the progressive development of the plant.

METHODS OF INVESTIGATION

In a previous bulletin (*9*) a description of the nature of growth of edible canna was given, together with a brief outline of the methods of investigation devised to study the progressive growth of the hill. Since these methods have been found useful in the present investigation a somewhat detailed discussion is included.

GENEALOGIZATION

In this study the hill was carefully dug to remove the entire clump of rootstocks unbroken. The clump was then carefully broken in half to locate the original seed and the rootstock or rootstocks directly attached to it, which are termed the first generation. The rootstocks directly attached to the first generation are the second generation, and so on. Thus, a hill can be dug after 12 months and the progressive stages of growth traced from the original seed rootstock.

CLASSIFICATION

In classifying the rootstocks in a hill they are grouped as (1) dormant, (2) mature, and (3) immature. The immature group is further divided into (*a*) rootstocks with little or no meristematic growth; and (*b*) rootstocks with meristematic growth. Since the transition from immaturity to maturity and thence to dormancy is rather gradual, it is deemed necessary to define the limits of each group in some detail.

The dormant group comprises plants on which the leaves have died and the stems have or have not yet shriveled.

In the mature group the oldest members still bear a green leaf at the apex, but the lower leaves are dead. The lower leaves are beginning to shrivel at the edges on the younger members and growth of new leaves at the apex has practically ceased. A stalk in the bud or bloom stage is placed in the mature group even though the basal leaves are still green.

The stalks of the oldest members of the immature 3*a* group have attained nearly full height with the basal leaves still green, whereas one leaf is beginning to unfold on the youngest members.

The oldest members of the immature 3*b* group have not yet begun to develop stalks, whereas the youngest members have just emerged from the bud stage. All members of this group are thus young "spikes." They are fresh in appearance and the basal scales show little sign of shrivelling at the edges. They are deep purple whereas the epidermis of the rootstock is pink at the apex.

Some spike rootstocks, the stalks of which fail to develop, remain in every hill. Usually either the parent or the offspring has a stalk and the "spike" is placed in the next younger group than the parent or the next older group than the offspring. A comparatively small "spike" which is attached to a mature rootstock and bears no offspring is classed as a part of the parent rootstock.

The division between the youngest members of the immature group (3*b* stage), and developing buds is necessarily inexact and relative. This division can not be based on size, which varies with the field and the stage of maturity. Usually, however, the uncertainty is small when the general rule is followed to classify as buds all those which have not become "sizeable" and have no definite "rounding in" at the attachment with the parent.

APPLICATION OF METHODS

Application of the above-outlined methods to edible canna of various ages and grown under widely different climatic conditions, has demonstrated that they have certain definite limitations. Genealogization, while comparatively simple in the first 8 to 10 months of growth, is rendered practically impossible with a hill 18 to 20 months old, by the death of the original stalks and the growth of one line of rootstocks over another, and its use is consequently restricted to determining the early tendencies of growth of individual hills.

In classifying plants the maturity of the stalks is taken as the measure of maturity of the rootstock. This is not always the case since often stalk growth is delayed and the rootstock may be old in appearance while the stalk is young and growing vigorously. Again, the lower leaves of a stalk may shrivel from excessive heat, drought, or wind, and thus be classed as Group 2, whereas the apical portion of the top is still immature and be classed as Group 3*a*. Subsequent findings, however, show a definite correlation between classification and the yields from monthly harvests on 0.1-acre plats and a much greater insight into the habit of growth of the plant than would have been possible with only general observations and notes.

RESULTS OF GENEALOGIZATION

Results of genealogization failed to show any consistent differences in the several plats because of the very large variations between the individual hills. For this same reason, however, the method was of value in selecting individual hills to determine desirable tendencies of growth in the hill, as is illustrated in Table 5.

TABLE 5.—*Comparison in generation of two hills, each 10 months old, of opposite tendencies*

Generation	Number of root-stocks	Weight of root-stocks	Average weight per root-stock	Number of stalks	Number of spikes
Hill No. 1:		*Pounds*	*Pounds*		
1	2			2	0
2	7			6	0
3	12			6	6
4	8			3	5
5	2			0	2
Total	31	13.5	0.44	17	13
Hill No. 2:					
1	1			1	
2	1			1	
3	3			3	
4	6			5	1
5	4			3	1
6	4			4	
7	1			1	
Total	20	20.6	1.03	18	2

The hills represent two extremes, one tending to stool rapidly and the other slowly. At the end of the third generation, hill No. 1 had 21 rootstocks in contrast with hill No. 2, which had only 5. As a result of the extreme tendencies, hill No. 1 had stunted rootstocks, whereas hill No. 2 had exceptionally large rootstocks which were proportionally greater in total weight and more desirable for starch manufacture.

The fact that there was a large number of spikes in hill No. 1, a small number in hill No. 2, and a similar number of developed stalks in both hills, would seem to show that the purpose of the spikes is to serve as storage organs. The death of the meristem of many of the spikes was at first thought to be the cause of their failure to develop stalks, but death more probably was the result of their long exposure in a dormant state.

SELECTION OF ROOTSTOCKS FOR "SEED"

A hill of canna contains a heterogeneous lot of rootstocks. A single hill 18 months old contains rootstocks which have been dormant

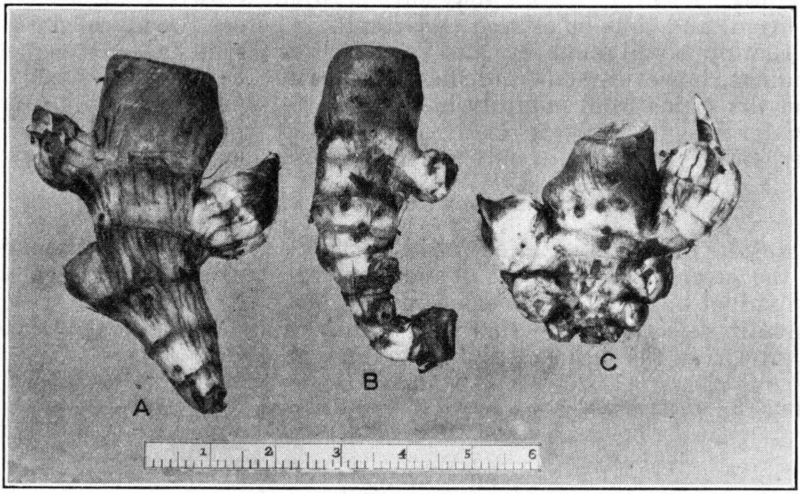

FIG. 7.—Subsurface types of canna seed: A, Second generation—note tapering shape and location of buds; B, first generation with only one bud remaining; C, first generation with eight buds

for nearly a year and others which are just developing, the different types varying in weight from a few ounces to more than 2 pounds.

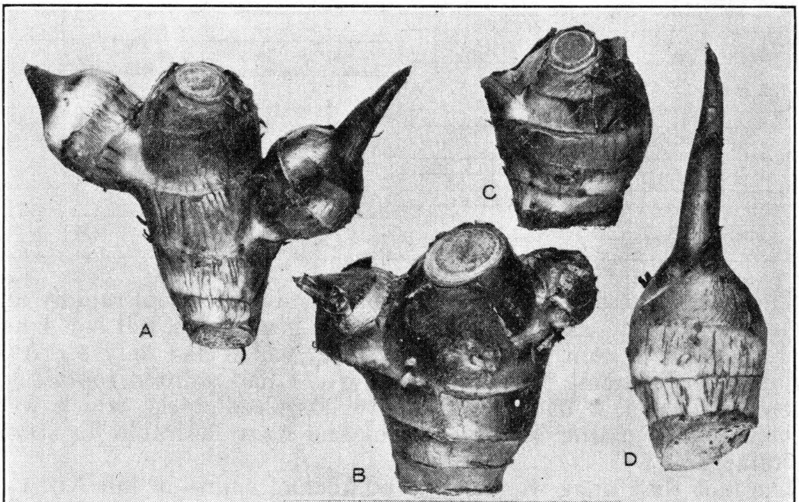

FIG. 8.—Immature surface types of canna seed: A, Well-developed attached spikes; B, small attached spikes; C, buds; D, no visible buds

Although the transition from one type of rootstock to another is gradual, the entire hill can be divided into a number of groups, each of which has distinct characteristics.

To determine the relative desirability of the different types of rootstocks for seed purposes, a portion of an 18-month-old field of canna was dug and the rootstocks were divided into six groups having the following characteristics:

Subsurface type (fig. 7).—Rootstocks of the subsurface type are small and cylindrical to tapering and constitute the first two generations. They exist in a dormant state in a hill 12 months old and their stems are dead. The rootstock grows beneath the surface of the soil in contrast with the surface types. The subsurface type has short internodes and may bear buds at practically every node from base to apex. As many as 10 have been observed on a single rootstock, although 2 and 3 are the rule. The buds, which are usually small, remain dormant until the newer growth of the hill is checked.

Immature rootstocks, surface type (figs. 8 and 9).—This type grows largely above ground and is oval shaped. The buds have large basal

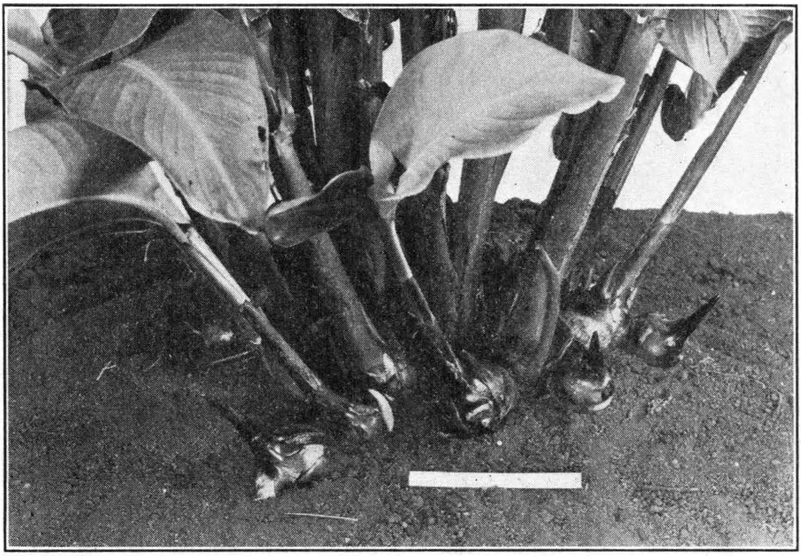

FIG. 9.—Base of hill of canna 5 months old

attachments to the parent and appear only near the apex of the rootstock. Usually two buds are seen, but occasionally a third appears which ordinarily does not develop. On some rootstocks of this group one bud has already reached the rootstock stage and has been removed, whereas on the youngest members only one bud has made its appearance. (Fig. 10.) The stalks of this group are immature and sometimes entirely undeveloped spikes. The group is further subdivided into (1) large rootstocks constituting the most vigorous and newest growth of the hill; and (2) small rootstocks constituting the secondary growth. (Fig. 11, A and B.) The secondary growth appears during the later stages of growth of the hill, or after the vigorous growth has been stopped by adverse weather conditions.

Attached spike.—This type is like the immature surface type except that one or both of the buds have developed into spikes which are not of sufficient size to be called rootstocks. For seed purposes the spike is left attached to the parent.

Detached spike.—In this type the spike is detached from the parent rootstock and used for seed.

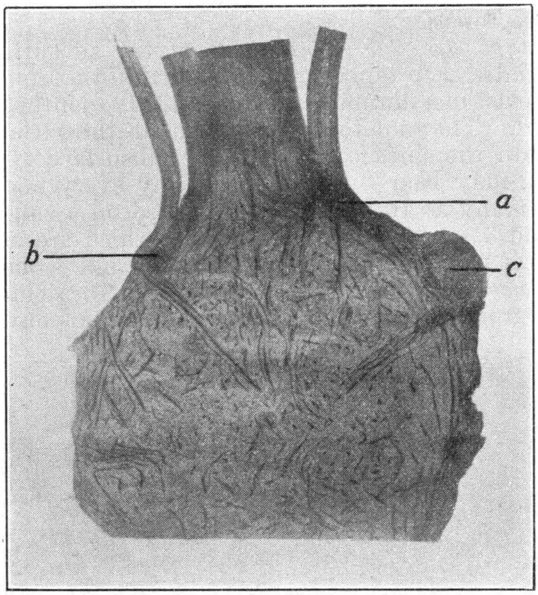

FIG. 10.—Bud formation on immature surface type of canna rootstock. The buds *c* and *b* constitute the vigorous primary growth of the hill; *a* usually remains dormant or produces a small secondary growth

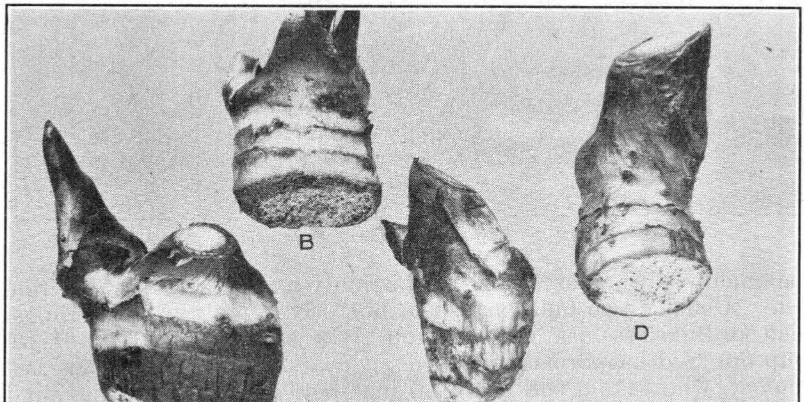

FIG. 11.—Secondary types of canna seed: A, Small, primary growth; B, C, and D, secondary growth

Mature rootstocks with dormant buds.—Usually one or two buds in this type have developed into rootstocks, and the remaining bud or buds exist in a dormant condition for many months. The parent stalk if developed must be either mature or dormant. To this type also belong mature rootstocks, the stems of which have never developed.

Rootstocks with no visible buds.—In this group are placed the older rootstocks the visible buds of which have already developed into offspring.

The several types of seed were planted in the experimental field July 10, 1924, and the resulting crop was harvested March 25, 1926. The hills were spaced 4 by 4 feet apart. Single hills were dug from the several plats from time to time for classification. Table 6 compares the yields and weights of single hills dug from the different plats at bimonthly intervals.

TABLE 6.—*Comparison in yield and weight of single hills dug from the seed-selection plats at bimonthly intervals*

Plat No.	Kind of seed	Date of harvest	Number of rootstocks per hill	Weight of hill	Average weight per rootstock
				Pounds	*Pound*
8	Subsurface rootstock	February, 1925	22.0	14.5	0.66
		April, 1925	22.0	15.3	.70
		June, 1925	19.0	14.1	.74
		August, 1925	27.0	21.7	.80
		February, 1926 [1]	56.6	36.5	.65
12	Immature rootstock (two buds)	February, 1925	23.0	14.0	.61
		April, 1925	26.0	19.5	.75
		June, 1925	28.0	22.8	.81
		August, 1925	41.0	35.2	.86
		February, 1926 [1]	57.7	42.1	.73
14	Mature rootstock (dormant bud)	February, 1925	18.0	11.0	.61
		April, 1925	31.0	13.5	.44
		June, 1925	----	----	----
		August, 1925	48.0	31.6	.66
		February, 1926 [1]	56.6	36.7	.65
15	Detached spike	February, 1925	12.0	7.0	.58
		April, 1925	17.0	6.5	.38
		June, 1925	23.0	15.0	.65
		August, 1925	36.0	18.0	.50
		February, 1926 [1]	39.3	25.4	.65
16	Attached spike	February, 1925	20.0	10.0	.50
		April, 1925	23.0	12.0	.52
		June, 1925	26.0	17.0	65
		August, 1925	44.0	29.0	66
		February, 1926 [1]	50.8	33.9	66
17	Immature rootstock (secondary)	February, 1925	15.0	6.5	.43
		April, 1925	18.0	7.5	.42
		June, 1925	19.0	13.8	.73
		August, 1925	----	----	----
		February, 1926 [1]	29.3	18.0	.62

[1] Average of four hills.

Table 6 shows clearly the initial depressing effect of two types of seed, namely, the detached spike and the secondary immature rootstock. It was not until June, 11 months after planting, that these two plats produced a vigorous growth. The differences in the results from the other types of seed are not pronounced and might easily be accounted for by individual hill variation.

Taken as a whole the period from February to June was one of slow growth with a general tendency toward increase in average weight. Beginning with August, there is apparent a sudden renewal of growth resulting in large increases in both number of rootstocks and weight of the hill. With the exception of plat 8, the six months period from August to February, 1926, was one of comparatively slow growth.

This irregular nature of growth of the edible canna is again discussed in a later section (p. 31).

Table 7 gives the yields of the different kinds of planting stock tested and the proportion failing to germinate.

TABLE 7.—*Yields and nongermination of different types of canna seed*

Plat No.	Kind of seed	Area of plat	Proportion of seed failing to germinate	Number of hills harvested	Gross yield per acre	Net yield per acre
		Acre	*Per cent*		*Tons*	*Tons*
8	Subsurface rootstock	0.100	8.5	217	41.6	37.3
9	Mature rootstock (no visible bud)	.100	77.7			
12	Immature rootstock (two buds)	.100	2.7	253	43.6	39.1
[1] 13	Immature rootstock (one bud)	.025	16.9	53	43.7	39.2
14	Mature rootstock (dormant bud)	.025	15.4	55	38.4	34.4
15	Detached spike	.025	32.3	47	34.1	30.5
16	Attached spike	.025	9.2	59	40.5	36.3
17	Immature rootstock (secondary)	.025	9.2	58	32.6	29.2

[1] In most of this seed one bud had developed into a rootstock.

It may be concluded from Table 7 that the large, immature rootstocks with two buds make the most desirable seed for planting. Large, immature rootstocks with one bud are equal in point of yield to those having two buds, but rather low in germination. Next in point of yield is the subsurface type, closely followed by the attached spike. With respect to germination these two types are decidedly superior to the immature rootstock with one bud. The mature rootstocks with dormant buds are somewhat less valuable in yield than the preceding types and rather low in germination. Detached spikes are too uncertain in germination and too low in yield to make desirable seed. Very small, immature rootstocks, although fair in germination, rank lowest in point of yield.

The rate of germination is dependent more upon the condition of the buds than on the type of seed. Buds on the subsurface type of rootstock usually are in good condition at the time of digging. A rootstock of this type bearing at least two buds is always preferable to a seed with one bud, because the buds at best are small, succulent, and easily damaged, and the percentage of germination tends to be low when only one bud is used. The buds of the immature type do not project from the parent seed sufficiently to be easily broken off, and, due to their freshness, they are seldom worm-eaten. The dormant buds on older rootstocks have been more or less exposed to worm and other injury and are not therefore as certain to germinate as are those of the types previously discussed. The attached spikes have many possibilities of germination. The terminal spike may grow; frequently the two "top" buds, one on each side of the spike, develop. In addition, a bud on the parent seed may be capable of development. Usually this type of seed is fully equal in point of germination to the two primary buds. The detached spike usually has no visible buds and germination proceeds from the dormant top buds. The buds on the very small, immature seed are of the primary type and are usually in good condition.

Obviously, no single set of experiments over one year can do more than indicate the most desirable type of seed for planting. Many unknown and variable factors remain for determination, even when the soil is uniform, the culture perfect, the weather normal, and the crop of the proper age for harvesting. Whether edible canna is sufficiently pure in type to obviate the effect of individual variation in the seed is unknown. The ultimate result of continuously planting one kind or size of seed to the exclusion of all others must be determined. The economic phases of the problem also await solution. A type of seed proving more desirable than others through repeated experiments may not be available during certain seasons of the year or stages of maturity of the crop. For example, many large, immature rootstocks with developing buds can be found during certain seasons with practically no attached spikes. Two months later these buds will have nearly all developed into spikes, with scarcely any developing buds. At other times neither spike nor bud is present in large numbers. Dependence upon one particular type of seed would probably be impractical.

Results of experiments in seed selection point to the elimination of at least three types—those with no visible buds, the small detached spikes, and the very small secondary kinds. With the elimination also of the dormant buds as questionable because of their long exposure to weather and insects the only desirable types remaining are the subsurface, the immature with one or two buds, and the attached spikes.

As the hill advances in age the proportion of desirable seed decreases. This decrease is due partly to the development of buds on the older rootstocks, but mostly to injury to the buds. On the other hand, nearly every rootstock is desirable for seed in a field where the fourth and fifth generations (usually at nine months) are developing. This fact suggests the possibility of digging young fields for seed purposes. The relative desirability of planting one carefully selected seed piece per hill or two less carefully selected seed can be determined only after data are obtainable on relative yields, percentages of germination, and cost of seed.

TREATMENT OF "SEED"

Rotted seed may be found in normal hills, but more frequently it is associated with particularly small or stunted hills. To determine the effect of chemical treatment on rot, three types of freshly dug canna rootstocks were exposed to the sunlight for 24 hours and then soaked in solutions of copper sulphate or mercuric chloride. The rootstocks were then dried in the sun for an hour and placed three per hill in the field. In order to produce conditions favorable for rot, the field was irrigated three times a week. The resulting crop was harvested after two months when the most advanced stalks were about 3 feet high. The results of treating seed with copper sulphate are given in Table 8.

TABLE 8.—*Effect of copper sulphate upon germination and rotting of edible canna rootstocks*

Kind of seed	Treatment	Proportion of rot in germinated seed	Number of seed germinated	Number of stalks	Appearance of stalks
Subsurface	$CuSO_4$, 5 per cent for 15 minutes	1/3	3	9	Good.
	$CuSO_4$, 5 per cent for 45 minutes	1/3	2	8	Poor.
	$CuSO_4$, 10 per cent for 15 minutes	1/3	2	7	Fair.
	$CuSO_4$, 10 per cent for 45 minutes		0	0	
	Control (no treatment)	0	3	9	Excellent.
Attached spike	$CuSO_4$, 5 per cent for 15 minutes	2/3	1	2	Medium.
	$CuSO_4$, 5 per cent for 45 minutes		0	0	
	$CuSO_4$, 10 per cent for 15 minutes		0	0	
	$CuSO_4$, 10 per cent for 45 minutes		0	0	
	Control (no treatment)	1/3	3	6	Medium.
Immature rootstock, two buds.	$CuSO_4$, 5 per cent for 15 minutes	2/3	1	4	Good.
	$CuSO_4$, 5 per cent for 45 minutes	2/3	2	9	Fair.
	$CuSO_4$, 10 per cent for 15 minutes	2/3	1	7	Poor.
	$CuSO_4$, 10 per cent for 45 minutes		0	0	
	Control (no treatment)	1/3	3	9	Excellent.

Copper sulphate did not prevent rotting of the seed. In fact, the treatment apparently increased the tendency to rot. Even the mildest treatment depressed germination. Of the three kinds of seed tested, the subsurface type was the most resistant both to the disinfectant and the rot. Partial rotting of the seed apparently had no effect on the vigor of the resulting plant, but where rot had penetrated to the portion of the seed adjoining the developing bud, there was a marked stunting of the stalks and a tendency toward profuse development of buds. Examination of the rotted seed showed somewhat darkened and watery tissue, nearly all of which was worm-infested. Although the worms feed mostly on decayed tissue they probably increased the rate of decay by opening fresh tissue. Rotting proceeded from the base of the seed where it had been attached to the parent, or along the side from which an offspring had been removed. (Fig. 12.)

Immersing lots of seed similar to those treated with copper sulphate in mercuric chloride in concentrations of 8 and 16 grams per gallon for periods of 15 and 45 minutes for each concentration did not have any toxic effect on germination or prevent rot.

Although edible canna rootstocks remain dormant and in excellent condition when they are left undug in the ground for 12 months (20 months after planting), they deteriorate rapidly upon exposure after digging. One of the causes of deterioration after digging may be discovered by evacuating a rootstock under water. Bubbles will rise from all parts of the surface and the rootstock will increase 8 to 10 per cent in weight. The moisture of freshly dug rootstocks evaporates rapidly through the epidermis, and the resulting influx of air opens the way for fermentation and decay. Since fermentation and destruction of sugars take place in 15 to 21 days (*9*), prolonged storage of the seed tends only to increase rot and to reduce vitality of the buds.

Frequent observations have shown that the original seed of a hill 18 months old is in excellent condition. At times rot appeared to have begun and to have partly destroyed the seed, while the remainder was quite sound. This was probably due to the fact that after the bud has developed a stem of good size the seed becomes an integral part of the plant and possesses all the rot-resistant qualities of the undug rootstock.

Rotting of the seed apparently does not injure the developing bud or the resulting plant when germination has not been unduly delayed. A canna rootstock weighing 8 to 12 ounces contains much more plant food than is needed for bud development, and rot usually begins at the base of the seed at its juncture with the parent, which part is farthest from the bud. The younger portions of the rootstock are much less susceptible to rot than the older portions. Hence, a healthy bud usually has sufficient time and plant food to develop normally before rot can penetrate to the upper portions of the seed. A faulty bud as the result of which germination is unduly delayed

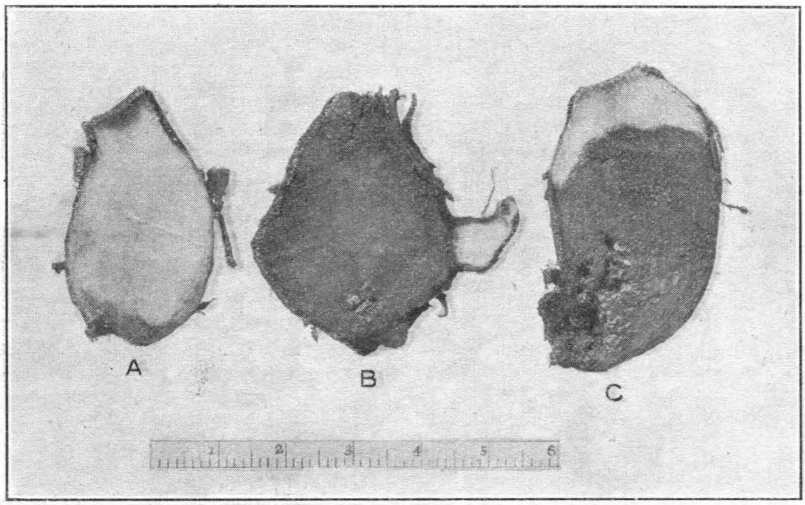

FIG. 12.—Rotting of canna seed after two months in the ground. The seed was dug, cut in half, and exposed to the air for 15 minutes. A, Sound seed which had developed a number of stems; B, rotted seed—rot had penetrated throughout the parent seed, but had not entered the developing bud; C, partly rotted seed, showing the progress of rot upward from the base of the rootstock—note the worm infestation at the base

will probably be found to be the cause of a stunted hill resulting from a rotted seed. Extreme conditions of moisture or drought facilitate decay. Seed which grows close to the surface of the ground or which is partly exposed is susceptible to rot. Fully 90 per cent of all the chemically treated and untreated lots of seed rotted to some extent in the soil which was kept excessively moist in the experiments for rot control.

Results of experiments conducted at the station would seem to indicate that seed for planting should be selected from freshly dug rootstocks. It should then be placed in bags for three or four days where a free circulation of air will heal the cut surfaces. The seed should always be carefully handled. Selection and bagging should be done in the field. The tender buds are very likely to be bruised when the seed is selected at the mill.

DEPTH OF PLANTING

The rootstocks of the edible canna are inclined to grow at or above the surface of the ground. (Fig. 13.) Many of them in a field 12 months old will be found growing several inches above the surface with no root system whatever. Such rootstocks usually are stunted. This tendency might be overcome by planting in furrows. Hilling-in gradually might further aid by raising the ground to a level with the ascending rootstock growth. An experiment was begun on a number of 0.1-acre plats to determine the effect on germination and yield of planting edible canna rootstocks at different depths, varying from 8 inches below the surface to the top of an upraised bed. Mill-run seed—that is, any type of seed with a visible bud—was planted

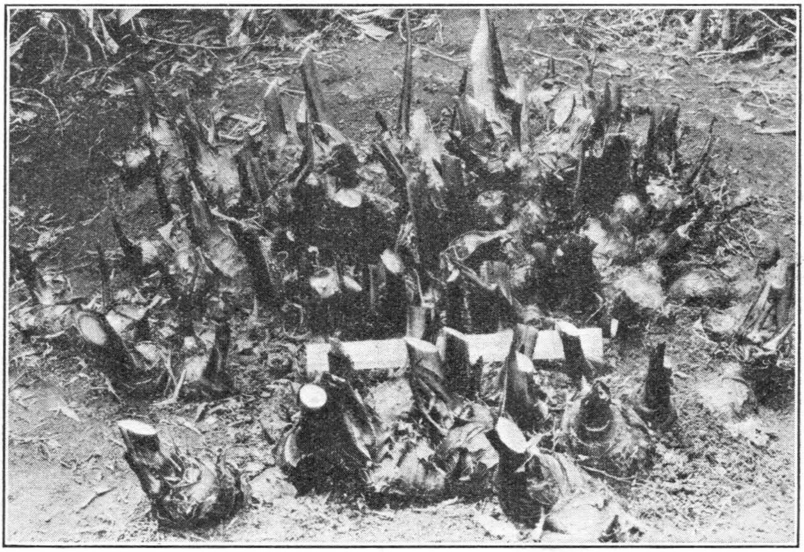

FIG. 13.—Base of a canna hill 22 months old. Note the tendency of the rootstocks to grow above ground

at intervals of 4 by 4 feet, and the resulting crop was harvested at 20 months. Table 9 gives the result of the experiment.

TABLE 9.—*Effect of depth of planting on germination and yield of edible canna*

Plat No.	Manner of planting	Proportion of rootstocks failing to germinate	Gross yield of rootstocks per acre	Net yield of rootstocks per acre	Average weight per rootstock
		Per cent	*Tons*	*Tons*	*Pound*
20	Hilled in gradually in 12-inch furrows	12.7	38.0	34.1	0.74
21	Planted in 12-inch furrows (not hilled in)	8.8	37.9	34.0	.67
22	Planted in an upraised bed	14.2	30.3	27.2	.59
23	Level culture; seed 8 inches deep	11.1	37.5	33.6	.71
24	Level culture; seed 1 inch deep	16.2	35.9	32.2	.68

Little difference in yield or average weight per rootstock was observed in the plats, except in the upraised bed which was decidedly inferior in both respects. Plat No. 20, in which the seed was planted in furrows and hilled in gradually, produced the highest yield and the largest and best preserved rootstocks. The strong winds of the Waimea district frequently blow over the succulent stalks of the canna plant and in so doing break the rootstock. Hilling-in sufficiently covered the rootstocks to save them from damage by the winds, which broke the stalks instead of the rootstocks. The same was true of plat No. 21 to a lesser extent. Plat No. 23 was superior in point of germination and yield to plat No. 24. In the latter plat the seed was planted close to the surface of the soil and germinated more slowly and with greater susceptibility to rot than was the case with plat No. 23.

Furrow planting is advantageous in preserving canna rootstocks, but the method is hardly feasible for the Waimea district. Not only are the furrows difficult to maintain in the loose soils of the district, but cross cultivation is impossible. This proves a serious disadvantage where hand weeding is expensive. It seems, therefore, that level culture, placing the top of the seed at least 4 inches below the soil surface, is the best method for the Waimea district.

NUMBER OF "SEED" PER HILL

The present local practice is to plant two or more seed pieces in the hill in the hope of increasing yield and eliminating the necessity of replanting. To determine the effect on yield of planting a number of mill-run seed in the hill, several plats were planted with one to four seeds per hill. The seed was set 4 by 4 feet apart, and the resulting crop was dug at 20 months. Table 10 gives the results of the experiment.

TABLE 10.—*Effect of number of seed per hill on germination and yield of canna*

Plat No.	Area of plats	Number of seed per hill	Proportion of seed failing to germinate	Gross yield of rootstocks per acre	Net yield of rootstocks per acre	Average weight per rootstock
	Acre		*Per cent*	*Tons*	*Tons*	*Pound*
10	0.10	1	15.0	35.2	31.6	0.55
11	.10	2	2.7	42.1	37.7	.58
18	.10	1	16.2	38.8	34.7	----------
19	.10	2	1.9	45.0	40.3	----------
9a [1]	.05	3	0	38.4	34.4	.72
9b [1]	.05	4	0	43.9	39.3	.61

[1] Plats Nos. 9a and 9b were planted seven weeks after the other plats in the area of plat No. 9 in which the seed failed to germinate in the seed-selection experiment.

Planting two or more seed to the hill reduced the percentage of nongermination to practically nil. The two-seed plantings yielded at the rate of 6.1 and 5.6 tons, respectively, greater than the corresponding one-seed plantings. The three and four-seed plantings, which are seven weeks younger, made practically the same yields as the one and two-seed plantings, respectively. It is doubtful whether the three and four-seed plantings would have greatly exceeded the one and two-seed plantings had they been allowed to grow another seven weeks.

The results would seem to show the superiority of the two-seed planting over one-seed planting. From the standpoint of yield, however, the advantages are small, since the additional seed weighs

1 to 1½ tons per acre, the cost of seed selection is doubled per acre, and the cost of planting is increased. For these reasons, planting three and four seed to the hill is hardly to be commended where the crop is grown on a large scale.

SPACING AND MULCHING WITH CANNA TOPS

In an experiment made to learn the effect of spacing on yields, edible canna plantings were made on 0.1-acre plats at distances of 2 by 4 feet, 3 by 4 feet, 4 by 4 feet, and 3 by 3 feet. Weeds encroached upon the zone of the resulting crop to such an extent as to render results unreliable. However, the present practice of planting at distances of 4 by 4 feet seems to be desirable for Waimea conditions. It permits cultivation during the first six months' growth of the crop. After this time weed growth is held in check by the luxuriant foliage which shades the ground. Planting at distances of 4 by 4 feet also permits cross cultivation, which is of considerable importance in eliminating hoeing.

The experiment made to learn the efficacy of mulching with edible canna tops was conducted on four 0.1-acre plats. The rows were top-dressed immediately after planting with a heavy and a light mulch of fresh, green tops and with partly dried tops. Mulching was expected to prevent weed growth in the row and also allow cultivation between the rows. All plats gave depressed yields. Mulching caused the seed to rot, depressed the rate and percentage of germination, and had little effect in reducing weed growth in the row. Part of the mulch remained green for some time, and this mulch and the weed growth acted as hosts for cutworms, which attacked the canna stalks. Mulching with canna tops apparently offers no advantage for the crop in the Waimea district.

FERTILIZERS

Observations on the growth of edible canna show that during the first three months after planting the crop grows very slowly and produces only one or two plants. It develops much more rapidly during the next three months and at the end of six months bears many vigorous stalks and a profusion of buds which are ready to develop. For these reasons fertilizer was thought to be more efficacious if applied to the crop a few months after planting rather than at the time of planting. It was thought also that a number of small applications would produce better results than one large application.

At the central station in Honolulu a fertilizer containing considerable amounts of nitrogen greatly increased top growth but did not materially increase yield. In the Waimea district mill-run seed was planted at distances of 4 by 4 feet on 0.1-acre plats, each of which was given a total of 100 pounds of fertilizer. The basal formula was nitrogen (N) 5 per cent (as ammonium sulphate), phosphoric acid (P_2O_5) 8 per cent (as superphosphate), and potash (K_2O) 10 per cent (as potassium sulphate). The field was harvested at 20 months. Table 11 gives the result of the experiment.

TABLE 11.—*Effect of time and number of applications of fertilizer on yield of edible canna*

Plat No.	Number of applications	Time of application	Gross yield of rootstocks per acre	Net yield of rootstocks per acre
			Tons	*Tons*
1	1	At time of planting	42.0	37.7
2	Control.		40.7	36.5
3	1	Three months after planting	41.9	37.5
4	1	Six months after planting	42.1	37.7
5	Control.		41.3	37.0
6	2	Three and six months after planting	43.2	38.7
7	3	At time of planting, and three and six months after planting	43.6	39.1

Although the response to fertilizer was slight, the fertilized plats made higher yields than the unfertilized (control) plats in all cases. Plat No. 7 gave the greatest increase in yield, 2.1 tons per acre. Weighings of individual hills showed no differences in average size of rootstocks in the fertilized and unfertilized plats. The value of the increment of 2.1 tons at $3.50 per ton is only $7.35, whereas the fertilizer applied cost $33. These data, while very fragmentary, would seem to indicate that on the rich and almost virgin soils of the best lands of the district, immediate fertilization is not necessary. However, analyses given in another part of this bulletin show that a crop of canna rootstocks removes the equivalent of 1,200 pounds of high-grade fertilizer from the soil. This heavy drain must eventually be met by equivalent returns of fertilizer. On the poorer lands of the district it is probable that an immediate response to fertilizer can be had.

TIME OF HARVESTING

The best age at which to harvest the canna crop is a much-disputed question. Since in Hawaii canna grows continuously though irregularly, it can not be definitely stated when the crop is mature. In Queensland, where growth is checked by cool weather and frosts during the winter, the crop is harvested at 10 months of age, or when the rootstocks "indicate their maturity by the triangular slit in the outer scale leaf of the bulb assuming a purple color."[3] However, it is further stated that the crop may be held over during the winter for a second season's growth. These observations do not seem to apply to Waimea where the climate is rather uniform.

To determine the monthly increments of growth, two 1-acre plats were planted with edible canna, one receiving seed at the rate of one per hill and the other at the rate of two per hill. The resulting crop was harvested from 0.1-acre areas in each plat every month, beginning with the ninth after planting and continuing through the twentieth month.

The following notes made from time to time show distinct differences in the growth of the crop:

February 12, 1925: Whole field growing vigorously. First blooms appearing and stalks 8 to 10 feet high. Many large spikes evident.

April 16: Last two months have been cold and wet. Vigorous growth of February apparently checked. Many spike rootstocks apparent with a large proportion of spikes dead, as is indicated by discoloration at apex of rootstock.

[3] Personal correspondence from H. C. Quodling, Director of Agriculture, Department of Agriculture and Stock, Brisbane, Queensland.

June 6: New top growth observed, also new leaves at apex of even the oldest stalks. The new tops are mostly of young Group 3*a*. A long break between the new and old stalks, which latter belong mostly to old Group 2. Some new rootstocks growing. New top growth is developing from old rootstocks growing in February.

August 8: Hard winds of past two months blew down many old stalks. Field looks like a new one. The new tops average medium to old Group 3*a*. New rootstocks apparent, but small.

November 17: A profusion of new spikes developing with little or no new top growth.

February, 1926: Very little growth of either stalks or rootstocks since November. Hard winds (kona) flattened most of the existing top growth. Many spikes beginning to develop,. New top growth expected.

Table 12 gives the monthly yields and tare of the crop.

TABLE 12.—*Monthly harvests and tare of one and two seed plantings from 0.1-acre plats*

Age of crop in months	Month of harvesting	Tare [1]	One-seed planting: Gross yield per acre	One-seed planting: Net yield per acre	One-seed planting: Monthly increment	Two-seed planting: Gross yield per acre	Two-seed planting: Net yield per acre	Two-seed planting: Monthly increment
		Per cent	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
	1925:							
9	April	12.7	15.09	13.17	----------	21.70	18.94	----------
10	May	12.7	17.25	15.06	1.89	26.50	23.13	4.19
11	June	11.0	18.75	16.69	1.63	28.58	25.44	2.31
12	July	15.5	18.60	[2] 16.37	----------	27.82	[2] 24.48	----------
13	August	12.1	23.20	20.39	[3] 3.70	30.25	26.59	[3] 1.15
14	September	11.4	29.85	26.45	6.06	33.23	29.44	2.85
15	October	15.3	32.90	[2] 28.95	2.50	37.00	[2] 32.56	3.12
16	November	8.9	38.20	34.80	5.85	40.90	37.26	4.70
17	December	8.0	40.75	37.51	2.71	44.25	40.71	3.45
	1926:							
18	January	9.9	44.93	40.48	2.97	46.55	41.94	1.23
19	February	9.8	47.60	42.93	2.45	48.70	43.93	1.99

[1] Tare was ascertained monthly by determining the proportion of adhering soil, roots, dead scales, and excess stems on about 200 pounds of rootstocks. (See also "Tare," p. 34.)

[2] The very high tare values, together with actual decreases in yields in two instances, brought into question the accuracy of the tare values. Therefore 12 per cent, the average tare of the other months up to November, was used to compute the tare weights.

[3] Increment based on June harvest since the yields in July were less than in June.

Table 12 shows a nearly continuous though irregular growth of canna from 9 to 19 months, inclusive. The rootstocks increased both in number and in weight. From April to July, inclusive, the rate of growth constantly decreased. Beginning with August, growth was resumed, reaching its maximum in November, when it again decreased.

For the first 12 months of growth (until August, 1925) the two-seed planting was decidedly superior to the one-seed planting. The July harvest of the former yielded 24.48 tons per acre net, whereas that of the latter yielded only 16.37 tons. Beginning with the thirteenth month the one-seed planting grew more rapidly than the two-seed planting and at 19 months it lacked only a ton of equaling the latter. These results are somewhat different from those given in Table 10, where the two-seed plantings are shown to have exceeded the one-seed plantings by 6.1 and 5.6 tons, respectively. The large monthly increments of the one-seed planting in the last seven months of growth may have been due partly to differences in seed or fertility of soil.

Sixteen hills were selected at regular intervals from each of the plats and classified according to the method outlined under "Classification," page 12. Table 13 gives the results.

TABLE 13.—*Classification of monthly harvests from one and two seed plantings from 0.1-acre plats*

NINTH MONTH (APRIL)

Group	One-seed planting			Two-seed planting		
	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
		Pounds	*Pounds*		*Pounds*	*Pounds*
1	0					
2	7.0	4.8	0.69	10.9	7.1	0.65
3 [1]	12.8	5.9	.46	16.9	8.4	.50
Hill [2]	19.8	10.7	.54	27.8	15.5	.56

TENTH MONTH (MAY)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	0					
2	9.3	6.5	0.70	11.6	8.9	0.77
3	13.1	7.9	.60	16.9	9.5	.56
Hill	22.4	14.4	.64	28.5	18.4	.65

ELEVENTH MONTH (JUNE)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	0.3	0.1	0.33	0.5	0.1	0.20
2	9.0	6.0	.67	12.8	8.9	.70
3	11.5	6.9	.60	15.5	9.8	.63
Hill	20.8	13.0	.63	28.8	18.8	.65

TWELFTH MONTH (JULY)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	0.4	0.1	0.25	0.9	0.4	0.44
2	10.2	7.3	.72	12.0	8.3	.69
3	9.9	5.7	.58	18.6	9.9	.53
Hill	20.5	13.1	.64	31.5	18.6	.59

THIRTEENTH MONTH (AUGUST)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	2.5	1.5	0.60	3.2	1.4	0.44
2	13.2	10.0	.76	13.8	9.3	.67
3	13.0	6.4	.49	17.7	8.8	.50
Hill	28.7	17.9	.62	34.7	19.5	.56

FOURTEENTH MONTH (SEPTEMBER)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	5.8	4.0	0.69	12.5	7.3	0.58
2	11.5	11.2	.97	14.6	12.1	.83
3	16.4	9.9	.60	19.5	8.4	.43
Hill	33.7	25.1	.74	46.6	27.8	.60

FIFTEENTH MONTH (OCTOBER)

Group	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
1	6.5	4.2	0.65	15.5	9.9	0.64
2	10.8	10.0	.93	16.0	12.7	.79
3	17.0	10.2	.60	18.8	8.3	.44
Hill	34.3	24.4	.71	50.3	30.9	.61

TABLE 13.—*Classification of monthly harvests from one and two seed plantings from 0.1-acre plats*—Continued

SIXTEENTH MONTH (NOVEMBER)

Group	One-seed planting			Two-seed planting		
	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks	Number of rootstocks	Weight of rootstocks	Average weight of rootstocks
		Pounds	*Pounds*		*Pounds*	*Pounds*
1	9.3	6.8	0.73	12.7	8.8	0.69
2	10.2	10.0	.98	14.4	12.9	.90
3	17.3	9.1	.53	17.2	8.6	.50
Hill	36.8	25.9	.70	44.3	30.3	.68

SEVENTEENTH MONTH (DECEMBER)

1	14.2	10.0	0.70	20.3	14.5	0.71
2	13.9	10.8	.78	15.2	11.3	.74
3	20.4	10.0	.49	20.1	8.8	.44
Hill	48.5	30.8	.63	55.6	34.6	.62

EIGHTEENTH MONTH (JANUARY)

1	15.0	11.1	0.74	22.5	14.1	0.63
2	9.8	8.5	.87	15.2	10.8	.71
3	20.7	10.4	.50	25.2	11.0	.44
Hill	45.5	30.0	.66	62.9	35.9	.57

NINETEENTH MONTH (FEBRUARY)

1	19.5	15.6	0.80	21.9	16.0	0.73
2	11.0	7.9	.72	16.6	10.4	.63
3	21.3	9.0	.42	21.1	7.7	.37
Hill	51.8	32.5	.63	59.6	34.1	.57

[1] Groups 3*a* and 3*b* are placed together since the division between these subgroups had to be changed a number of times. This does not affect the total for Group 3.
[2] Each "hill" is the average of 16 classified hills.

A consideration of Table 13 shows that the first rootstocks of Group 1, dormant stage, first appear in the eleventh month harvest. After that time the number increases rapidly. (Figs. 14 and 15.)

Group 1 shows a very close correlation in both the one and two-seed plantings with the hill as a whole, and the increases in the monthly harvests beginning with August.

Group 2 shows little correlation either with the number of rootstocks or weight of the hill as a whole. In the two-seed planting the number gradually increases from 10.9 at 9 months to 16.6 at 19 months, whereas, in the one-seed planting it increases from 7 at 9 months to 13.2 in the thirteenth month, and thence decreases with one exception to a fairly constant level of between 9.8 and 11.

In Group 3 the number remains roughly constant in the two-seed planting until the seventeenth month, ranging from 15.5 to 19.5, with a sharp increase to 25 at 18 months. In the one-seed planting the number decreases from 13.1 in the tenth month to 9.9 in the twelfth month and increases steadily to 21.3 in the nineteenth month.

In average weight per rootstock, Group 1 of the two-seed planting has an initial value of 0.2 pound in the eleventh month and a final value of 0.73 pound at the nineteenth month. Group 1 of the one-seed planting has an initial value of 0.33 pound in the eleventh month and a final value of 0.8 pound in the nineteenth month.

In average weight per rootstock, Group 2 of the two-seed planting was fairly constant, ranging from 0.65 to 0.83 pound, until the

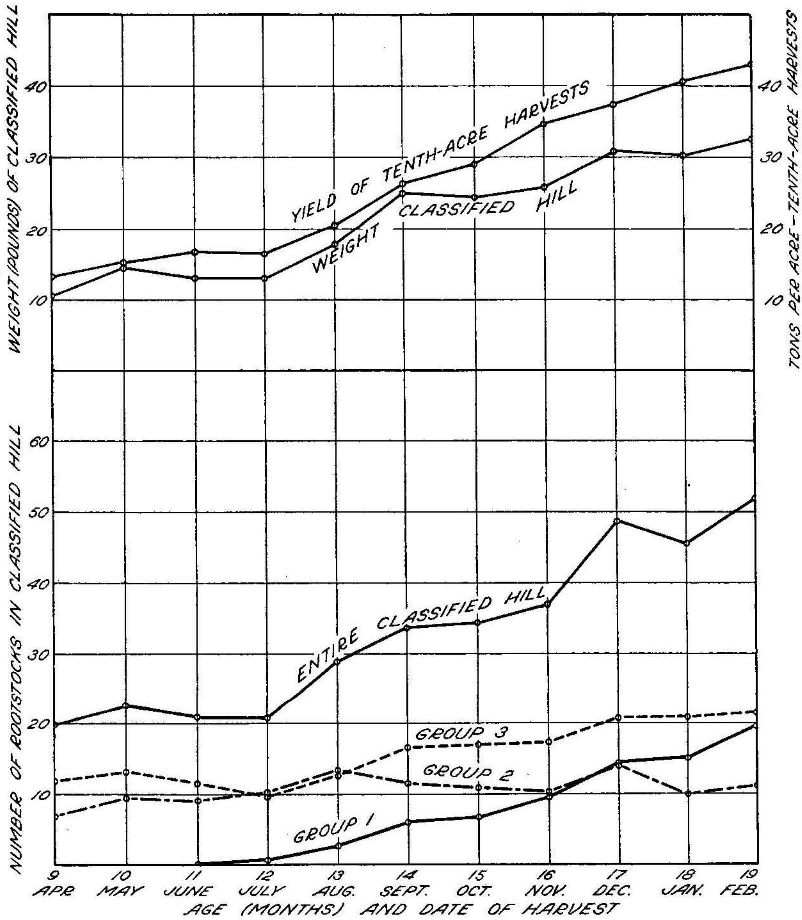

FIG. 14.—Tenth-acre harvests and classifications of "one-seed" plat

fourteenth month; it increased to 0.9 pound in the sixteenth month, and subsequently decreased to 0.63 pound in the nineteenth month. A similar variation occurs in the one-seed planting, the maximum at the sixteenth month being 0.98 pound per rootstock.

The close correlation in results between the one and two-seed plantings together with the classification would seem to verify the essential accuracy of the results, notwithstanding changes due to variations in seed, soil, and tare values.

The comparatively small increases in the yields during June and July, the sudden increase beginning with August, and the appearance of Group 1 in appreciable numbers indicate a cyclic rather than a continuous growth of the plant. (Fig. 16.) From February until May few new rootstocks appeared and practically all the stalk growth was mature, Group 3 consisting largely of spikes. New stalk growth appeared in June and many new rootstocks in August. If these phenomena are inherent in the plant, the first cycle of growth ended

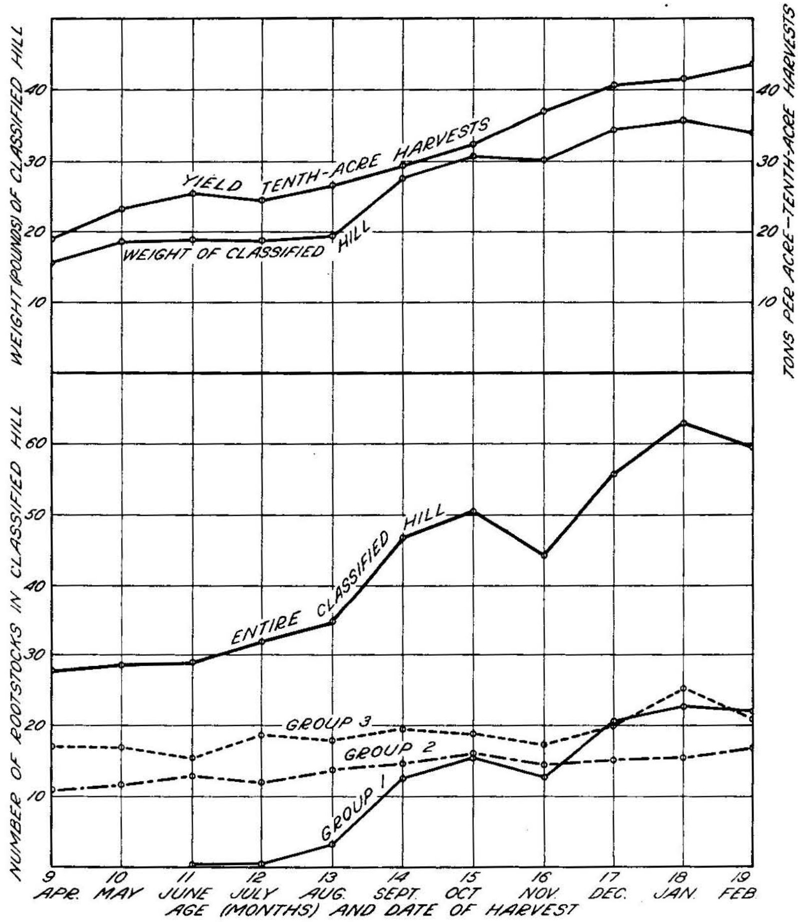

FIG. 15.—Tenth-acre harvests and classifications of "two-seed" plat

about June, and the two or three earlier months constituted the maturing period. The sudden new growth of stalks in June and new rootstocks in August might then indicate the beginning of the second cycle of growth.

Climatic factors undoubtedly have their effect on growth. Except for young fields planted six to eight months or less, observations show a similarity in the growth of fields of different ages in the same locality. Among the climatic factors, destructive winds have a bearing on the crop. During December, 1925, for example, a severe wind flattened most of the stalk growth, which was shortly replaced by numbers of new stalks. (Fig. 17.) Growth proceeds irregularly

FIG. 16.—Cyclic growth of canna plants, 14 months old. Note the first cycle of old mature tops and the second cycle of young immature stems

regardless of whether the cyclic tendency is inherent or climatic, or a combination of both. A field at one stage may appear rather old with most of its stalks having only the apical leaves green; the same field three months later may appear quite young due to its profusion of new stalk growth. Two months later still, new rootstocks in appreciable numbers may be found growing. This would seem to be the order of growth rather than a steady, simultaneous growth of rootstock and top. The cyclic tendency is partly masked in the results of monthly harvests since growth within the rootstock increases the yields regardless of whether new rootstocks develop.

Previous consideration of the relation of classification to growth indicated the contemporaneous appearance of Group 1 with the sudden increases in the new growth of the hill. Moreover, the curve for this growth follows very closely the curve for the total number of rootstocks in the hill. Whether this is the cause or the effect of the new growth is not known, however. Of the three groups, Group 2 would naturally be expected to be the most constant and

FIG. 17.—Cyclic growth of canna plants, 24 months old. Note the vigorous top growth which has sprung up as the result of a windstorm which blew down all the old stems. The rootstocks are nearly all undersized.

to show a tendency toward gradual increase as the size of the hill increased. This is well exemplified in the two-seed planting.

The results of Group 3 show little correlation between the irregular and the cyclic nature of the new growth of the hill. Unfortunately a definite division was not established between the subgroups 3*a* and 3*b* [4] during the progress of the experiment. Obviously, a group comprising all the stages of growth from that of the youngest spike up to the mature stage would hardly indicate monthly variations. Moreover, after a long dormant period a spike may develop a stalk and thus remain in Group 3*a* much longer than would be the case did the stalk develop normally. Apparently Groups 2 and 3 together maintain a relatively constant but slowly increasing number of rootstocks in the hill, the increase in the total number in the hill being largely accounted for in Group 1.

[4] Since the completion of this investigation the classification method has been revised, Group 3 being further subdivided into Group 3*c* which includes those rootstocks just emerging from the developing bud stage. In addition the number of spikes and stalks are noted in each group. It is belived that these revisions will furnish data concerning the top growth and make the method more responsive to new growth in the hill.

The small average weight of rootstocks in Group 1 during the months of June and July is due to the fact that the first rootstocks which become dormant are of the small cylindrical type. During the subsequent months the larger surface types pass over into Group 1, thus giving rise to rapid increases in average weight until at the nineteenth month this value exceeds that of the other groups.

A number of factors are to be considered in determining the proper age at which to harvest the canna crop:

(1) The total yields continue to increase up to 19 months, and probably until the rootstocks of Group 1 ultimately rot, at which time the value would become constant. From the standpoint of total yield harvesting should be deferred until the dormant rootstocks begin to deteriorate, which usually takes place between 18 and 24 months. Cultivation ceases after the first 6 or 7 months and the only expenditure for increase in yields after this period is for rental of the land occupied by the crop.

(2) The manufacture of clean, white starch becomes increasingly difficult after the plants reach a certain stage. Even though the oldest rootstocks have not actually begun to rot they become watery and discolor quickly when opened, and the cortex becomes dry and corky. The surfaces of the rootstocks which have been broken by the action of the wind partly decay and exude sap which mixes with the soil and forms a hard mass. Although the starch granules apparently are not affected under such conditions, the discolored tissue and adhering soil interfere materially with the refining of the product.

(3) As the hill grows beyond a certain stage, much of the younger growth of its rootstocks is small. This fact is not perceptible from a distance. The field may have a strong, vigorous top growth and stunted rootstocks. The latter may add considerably to the weight of the hill, but they are not desirable for starch manufacture. Not only do they increase the difficulties incident to washing but they are low in actual starch content.

(4) In a previous bulletin *(9)* the starch content of a canna rootstock was shown to vary from 2.08 to 27.92 per cent, Group 3 containing the lowest. Obviously a field having a comparatively large part of its total weight in this group would yield less starch per ton of rootstocks than it would if this growth were allowed to reach the Group 2 stage. In practice this point is hard to determine because of the prevalence in the field of new growth at all times. However, the relative proportion of Group 3 to the total weight of the hill decreases from approximately 50 per cent at 9 months to about 25 per cent at 19 months. It is concluded, therefore, that the longer the hill remains in the ground the higher will be the proportionate yield of rootstocks of high starch content.

Before the proper age at which to harvest the crop can be definitely determined experiments similar to the one undertaken will have to be repeated many times to take into account different seasons, times of planting, and soils. The available data seem to show that the crop should be allowed to grow until the new growth becomes of undesirable size, or until the dormant Group 1 gives signs of deteriorating. In the foregoing experiment this would be between 17 and 18 months.

TARE

In harvesting edible canna considerable dirt, dead scales, and leaves adhere to the rootstocks and must be deducted from the gross weight in determining the net production of material for use in starch

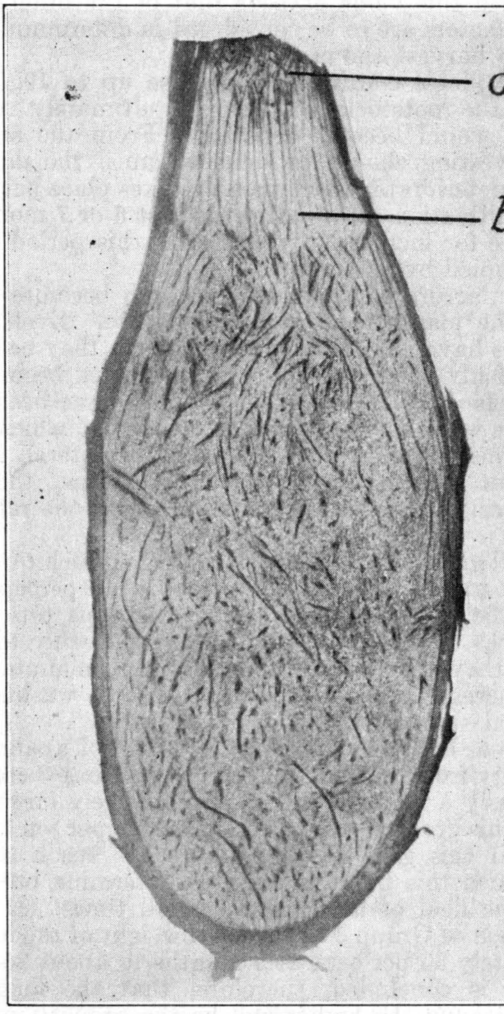

FIG. 18.—Juncture of stem and rootstock of canna. *a* Indicates the apex of the rootstock, the stem being characterized by parallel vascular bundles

manufacture. Table 12 (p. 26) shows that the tare varies considerably from month to month. During the early part of the harvests the percentages ranged from 11 to 15.5, whereas later they varied from 8 to 9.9. The variations are due partly to the fact that harvesting on a large scale is as yet an unstandardized procedure, and partly to the employment of untrained help in the work of harvesting, making it impossible to insure that the tops are severed with the same average length of stem attached to the rootstocks. In addition, the quantity of roots, dead scales, and soil adhering to the canna rootstocks varies under different weather conditions.

Lack of precision in cutting off the top at the exact apex of the rootstock makes it difficult also to estimate the tare. In the subsurface types the exact juncture of rootstock and stalk can be determined only by a careful inspection of a longitudinally cut section of the rootstock. (Fig. 18.) During later harvests great care was taken to cleanse the rootstocks of all adhering soil and to cut the tops as closely as possible to the rootstocks so that the tare values would be more nearly constant. The values can not be assumed to be constant, however, since they are so easily affected by the factors mentioned above.

The tare will likely have to be estimated in actual operation, especially if the rootstocks are purchased by the ton from growers. Two methods of procedure are feasible for the purpose. One is that used in the present study. If accurate results are expected considerable care must be exercised in the selection of representative samples and determination must be made on lots of good size. In the second method, the price per ton is based on the percentage of starch extracted. A basic price could be paid plus a bonus for each percentage of extraction over the minimum. The actual percentage of starch in the rootstock could be determined by attaching a continuous sampler to the shredder. The second method seems preferable to the first since it takes into account the tare and also differences in actual percentage of starch in the rootstock. However, this method can not well be used until milling operations are completely standardized. The first method can be used during the initial stages of the industry.

FEED AND FERTILIZER VALUE OF CANNA TOPS AND PULP

In order to determine the fertilizer elements in the different parts of the canna plant and the value of these parts as feed and as green manure, 5 hills of canna were dug from an 18-month-old field at Waimea. The tops were classified and the separate groups weighed. Approximately 50 pounds of rootstocks were shredded and the starch extracted by repeatedly washing the pulp in a cloth bag. Samples of the pulp, the rootstocks, and the three groups of tops were then dried and analyzed for their nutritive and fertilizer constituents. Group 1 contained an even distribution of shriveled tops and tops the stems of which were still succulent. Group 2 also contained an even distribution of the older and younger members. Group *3a* was largely medium to old and contained practically none of the youngest stalks of the group. Table 14 compares the composition of different parts of the canna plant and other carbohydrate feeds.

TABLE 14.—*Composition of different parts of the canna plant and other carbohydrate feeds*

Material and source	Water	Fat	Crude protein	Fiber	Nitrogen-free extract	Ash	Nitrogen	Lime	Phosphoric acid	Potash	Nutritive ratio 1 to —
Edible canna (air-dried material):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Tops, Group 1	10.14	0.46	3.35	31.93	47.95	6.17	0.54	1.29	0.51	1.15	14.6
Tops, Group 2	10.18	.55	5.36	21.67	54.05	8.29	.86	.93	.78	2.48	10.3
Tops, Group 3*a*	11.24	.79	7.46	21.43	48.48	10.60	1.19	.78	.76	3.52	6.8
Rootstock	4.36	.34	2.83	2.45	85.29	4.73	.45	.10	.62	1.32	30.5
Pulp	7.03	.31	1.99	9.78	78.46	2.43	.32	.27	.63	.79	39.5
Edible canna (fresh material):											
Tops, Group 1	77.00	.12	.86	8.17	12.27	1.58	.138	.330	.131	.294	-------
Tops, Group 2	89.00	.07	.66	2.64	6.62	1.01	.105	.113	.095	.302	-------
Tops, Group 3*a*	89.70	.09	.86	2.49	5.63	1.23	.138	.090	.088	.408	-------
Rootstock	77.28	.08	.67	.58	20.27	1.12	.107	.024	.147	.313	-------
Pulp [1]	77.28	.08	.49	2.39	19.17	.59	.078	.067	.154	.192	-------
Other comparable feeds:											
Sugar-cane tops [2]	74.47	.42	1.54	7.31	14.71	1.55	.246	-------	-------	-------	10.2
Corn fodder [3]	79.30	.50	1.80	5.00	12.20	1.20	.290	-------	.110	.390	7.4
Timothy hay [3]	13.20	2.50	5.90	29.00	45.00	4.40	.940	-------	.330	1.420	8.6
Potato pomace [3]	12.00	1.06	7.42	10.61	65.72	3.19	1.080	-------	.240	1.080	9.2
Cassava starch refuse [3]	12.00	.70	.80	6.10	78.80	1.60	.120	-------	.060	.280	100.5
Dried beet pulp [2]	8.40	.70	8.10	17.50	60.80	4.50	1.290	-------	.220	.310	7.7

[1] Calculated to same moisture basis as rootstocks.
[2] (*4, p. 3*).
[3] (*3, app., Tables I, III.*) Potato pomace and cassava starch refuse were calculated to air-dry basis.

A comparison of the composition of the air-dried material of the three groups of canna tops and the rootstock shows a gradual decrease in fat, protein, and ash in progressing from Group 3*a* to Group 1 and thence to the rootstock. In carbohydrates the tops and rootstocks vary greatly, due of course to the storage of starch in the latter. Lime increases with the increase in maturity of the stem but drops to a very low value in the rootstock. Phosphoric acid and potash decrease in the older tops but there is a slight increase in these elements in the rootstock over the proportion in the oldest tops.

In estimating the value of edible canna tops as green feed, Group 1 should not be considered because it consists of dried leaves and partly shriveled stems which are fibrous and unpalatable. The greater moisture content of the other two groups over that of sugar-cane tops and corn fodder decreases their fresh green value. Reduced to the same moisture content, the three feeds have similar value.

In fertilizer value, the average of the three groups is similar to the fertilizer value of corn fodder in both phosphoric acid and potash.

Canna pulp as a feed is only slightly poorer than the original rootstock. There is somewhat less nitrogen-free extract and protein in the pulp than in the original rootstock, and the ash content decreases to half the quantity in the rootstock due largely to losses in potash. In comparison with the other by-products, canna pulp is decidedly poorer in protein and richer in carbohydrates, with a correspondingly wider nutritive ratio, than potato pomace and dried beet pulp. As compared with cassava starch refuse, canna pulp is richer in protein, but has a much narrower nutritive ratio.

During the process of manufacture water is used copiously to remove the starch from the shredded rootstock. This washing is done on screens of 60 to 80 meshes to the inch, so that in addition to the starch, certain quantities of cellular tissue, colloidal material, and water-soluble constituents pass through the screen and are subsequently separated from the pure starch by fluming and levigation.

In order to approximate the quantity of the various constituents of the rootstock lost during manufacture and the proportion retained by the pulp, the analysis of the pulp (Table 14) was recalculated to percentages of the original rootstocks. In this recalculation the values for the pulp were multiplied by the factor 0.58/2.388, the numerator being the fiber content of the rootstock and the denominator representing that of the pulp, it being assumed that the fiber was not affected by the washing process. Table 15 shows what constituents are retained by the canna pulp during the process of manufacture.

TABLE 15.—*Constituents of canna rootstocks retained by the pulp during the process of manufacture*

Constituent	Rootstock	Pulp	Proportion in pulp of original rootstock [1]	Proportion in pulp of constituents of rootstocks [2]
	Per cent	*Per cent*	*Per cent*	*Per cent*
Moisture	77.284	77.284		
Fat	.081	.076	0.019	23.5
Protein	.671	.486	.119	18.0
Fiber	.582	2.388	.582	100.0
Nitrogen-free extract	20.260	19.173	4.672	23.1
Total ash	1.122	.593	.145	12.9
Lime (CaO)	.024	.067	.016	66.7
Phosphoric acid (P_2O_5)	.147	.154	.037	25.2
Potash (K_2O)	.313	.192	.047	15.0

[1] Column 3 times factor 0.58/2.388. [2] Column 4 divided by column 2.

Table 15 shows that the proportions of the various constituents retained by the pulp are, with the exception of that of lime, very small.[5] Potash is leached out to the greatest extent, followed by protein, carbohydrates, fat, and phosphoric acid, in the order named. Lime is outstanding in that it is retained in the pulp to more than twice the extent of any of the other constituents. The predominance of lime in the stems (Table 14) suggests that it is contained largely in the more fibrous tissue of the rootstock and hence is less subject to leaching than are the other constituents.

Table 16 shows the pounds per acre of fertilizer elements contained in one crop of edible canna. The composition and weights of the tops and rootstocks are based on the harvest of the five hills used in the analysis given in Table 14. The "proportion in pulp of original rootstocks" (Table 15, column 4) is used in estimating the values for the pulp.

TABLE 16.—*Fertilizer elements in one crop of edible canna from 1 acre*

Part of plant	Weight per hill	Weight per acre	Nitrogen	Lime	Phosphoric acid	Potash
Tops:	*Pounds*	*Tons*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Group 1	5.2	7.1	19.6	46.9	18.6	41.7
Group 2	26.8	36.4	76.5	82.3	69.2	219.9
Group 3a	4.6	6.3	17.4	11.3	11.1	51.4
Total	36.6	49.8	113.5	140.5	98.9	313.0
Rootstocks	22.4	30.0	64.2	14.4	88.2	187.8
Whole plant	59.0	79.8	177.7	154.9	187.1	500.8
Pulp			11.5	9.6	22.2	28.2

[5] Based on the assumption that the fiber was 100 per cent retained.

Table 16 shows that the top growth of canna requires considerably more fertilizer elements than do the rootstocks. The former require 10 times as much lime as the latter, about double the quantities of nitrogen and potash, and nearly equal quantities of phosphoric acid. Stated in terms of commercial forms of fertilizer, the tops require 680 pounds of nitrate of soda, 250 pounds of limestone, 495 pounds of superphosphate (acid phosphate), and 616 pounds of sulphate of potash, representing a total of 2,041 pounds of fertilizer returned to the soil when the tops are plowed under. The rootstocks remove from the soil approximately 385 pounds of nitrate of soda, 26 pounds of limestone, 441 pounds of acid phosphate, and 376 pounds of sulphate of potash, or a total of 1,228 pounds. The pulp contains 69 pounds of nitrate of soda, 17 pounds of limestone, 111 pounds of acid phosphate, and 56 pounds of sulphate of potash, totaling 253 pounds. If the pulp and tops are returned to the soil the crop will remove the equivalent of 975 pounds of fertilizer.

The immature tops of edible canna are very palatable and make a nutritious green feed. Nearly all the leaves of the mature (dormant) tops have shriveled, and the fibrous stems, although not very palatable, if finely cut might be used as feed because of their sugar content. If the whole top growth of the hill could be cut so as to avoid hand selection and fed fresh or as silage, quantities of the tops might be used on the near-by ranches for green roughage. The top growth is worth more than a dollar per ton when left on the land for its fertilizer elements.

Field methods of successfully handling the tops as green manure have not yet been developed. If the field is cross disked immediately after harvesting with a heavily weighted disk, the tops can probably be cut into short lengths and plowed under. They will soon rot if kept moist. Decomposition may also be effected by placing the tops in piles or windrows across the field. The repeated incorporation in the soil of such heavy applications of succulent green matter may eventually have a deleterious effect. Allowing a partial drying out of the tissue after disking and before plowing under would be advantageous from this standpoint.

The apparent palatability of the waste pulp from the starch factories suggests its use as a carbohydrate feed. It is comparatively low in protein, but high in carbohydrates, and not excessively high in fiber content. Locally used pulp can be taken from the factory direct to the animals. The pulp is dried in the same manner as starch for shipping. The dried pulp is a mixture of long, coarse fibers and fine tissue. Grinding and sifting facilitate separation of the long fibers from the pulp proper, which then has the consistency of bran. To the pulp can be added the brown sludge which is separated from the starch during purification.

MANUFACTURE OF STARCH

After the tops have been cut, the rootstocks are dug by means of a tractor-drawn middle burster having a high beam. They are then carried to the mill for starch-making. (Fig. 19.) The washing machine consists of a horizontal, cylindrical iron drum 3½ by 12 feet with iron slats for sides. The slats are 2 inches wide and are separated by intervals of an inch. The drum has attached to its perimeter a worm running the entire length. Wooden cleats running parallel to the long axis of the drum are attached at intervals between successive threads of the worm. The rootstocks are fed into the drum which rotates partly under water; thence they are worked by means of the worm to the opposite end of the cylinder. The wooden cleats, which alternately lift and drop the rootstocks, facilitate the washing. The rootstocks are next run into the hopper of the grater. This consists of a sheet of perforated iron which has been fitted on a wooden cylindrical core 36 inches long and 24 inches in diameter to form the grater. It revolves about 300 times a minute. Water is copiously used in the grating process to facilitate shredding and to keep the grater clean. The pulp from the rasper is then led into a revolving cylinder the surface of which is covered with brass screening (60 meshes to the inch). The cylinder is 9 feet long and 3 feet in diameter. Fully 90 per cent of the extraction is done by this machine. The pulp is sprayed with water and passed from the revolving screen

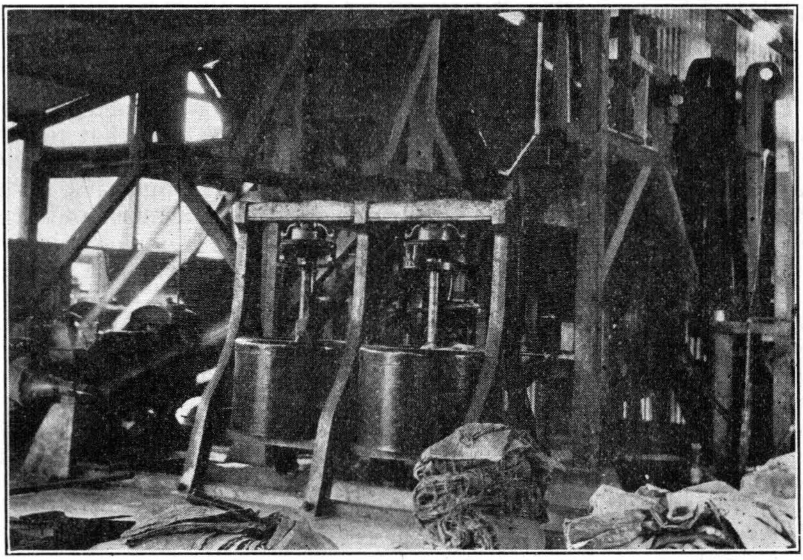

FIG. 19.—Interior of a starch mill at Waimea, Hawaii

to the first beater. This is a sheet-iron cylinder 2 feet in diameter and 8 feet long having paddles which revolve at the rate of 240 times a minute attached to the shaft. The beater breaks the clumps of pulp and releases more starch. The pulp then is carried from the first beater to the first shaking screen (80 meshes to the inch). This screen is 4 feet wide, 10 feet long, and has a pitch of 6 inches. It is driven by means of an eccentric which works the pulp gradually down the surface. Water is again sprayed over the pulp as it passes down the screen to facilitate further the extracting of the starch and the pulp is then passed into a second set of beaters and screens.

The starch water from the three screens is then combined and passed through a set of three shaking screens 2 by 6 feet each (80, 100, and 120 meshes, respectively, to the inch) for the removal of fine particles of pulp. The starch water is then run into the flumes. These are 140 feet long, 18 inches deep, and 18 inches wide, and are set at a pitch of 6 inches to 140 feet. The starch settles in the upper part of the flume, permitting the lighter particles of brown tissue to be carried off. In the refining process the starch is flushed out of the flumes into settling tanks 4 by 6 feet and 3 feet deep. By repeated levigation and removal of the brown sludge, a comparatively pure form of starch is secured. After the final settling the starch is agitated with water and pumped into a 30-inch sugar centrifuge. This machine reduces the moisture content of the starch to about 40 per cent and lessens the time involved in drying the starch by heat. The starch is then broken into fine pieces and placed on trays. These in turn are placed for 24 hours in a tunnel drier 80 feet long, 6 feet wide, and 7 feet high and resembling the ordinary counter-current fruit dehydrator. The dried starch finally is powdered and put into packages for marketing.

The starch may be shipped from the factory either by way of the seaport of Kawaihae, 12 miles distant from Kamuela, which is located at the western edge of the agricultural area, or by railroad, which terminates at Paauilo, 18 miles to the eastward.

SUMMARY

The possibilities of the Waimea district as a canna-producing region has led to experiments with the crop on a field scale in that region.

The Waimea district is a slightly rolling table-land (2,700 feet elevation) between Mauna Kea and the Kohala Mountains. The district is characterized by strong winds and frequent mists and fogs. The soil is of a porous nature and is derived largely from volcanic ash. Most of the soil of the Homestead tract is very fertile.

The Waimea district is devoted to small diversified farming, but has need of a staple field crop which can be grown throughout the year and readily converted into cash. Edible canna gives promise of filling this need provided the crop can be utilized as a commercial source of starch. The crop is especially well adapted to the region notwithstanding the comparatively low annual rainfall (43.5 inches).

Methods of study of the edible canna are outlined which make possible the progressive study of the growth of the plant.

Results of field experiments indicate the desirability of "seed" selection. Of the various types of rootstocks, the immature rootstocks with one or two buds gave the highest yields, followed by subsurface and attached spike types. Mature rootstocks with no visible bud, detached spikes, and secondary immature rootstocks should be thrown out in selecting planting stock.

Chemical treatment of seed did not prevent rotting. Rotting of the seed does not affect the growth of the hill unless development of the bud is delayed. Under Waimea conditions, seed should be planted at least 4 inches deep and at distances of 4 by 4 feet to permit cross cultivation. Planting two seed pieces per hill insures better germination and increases the yields somewhat but also increases the costs of seed selection and planting. Mulching with canna tops retarded germination and was not successful in preventing weed growth. Fertilizers failed to increase the yields of rootstocks appreciably. This is attributed to the high fertility of the soils on the experimental field.

Results of monthly harvests (ninth to nineteenth month, inclusive) from one and two-seed plantings on 0.1-acre plats showed an irregular but nearly continuous growth and unusually high yields of rootstocks.

At the end of the nineteenth month the two-seed planting yielded 43.93 tons per acre and the one-seed planting, 42.93 tons. The crop should be allowed to grow until the new growth produces rootstocks of undesirable size for starch making, or until the older rootstocks show signs of deteriorating. For starch manufacture the crop should be harvested at 17 to 18 months.

Progressive studies of the growth of the plant showed it to be of a cyclic nature rather than uniform. Periods of comparative dormancy were followed by periods of rapid growth. Probably this is partly inherent in the plant and partly due to climate.

Analyses of the different parts of the canna plant show that the tops are of value both as feed and as fertilizer. The stalks from an acre of land contain the equivalent of over a ton of high-grade fertilizers. An acre of rootstocks removes from the soil the equivalent of 1,200 pounds of fertilizer. During the process of manufacture the pulp loses about four-fifths of the total fertilizer elements contained in the rootstocks. The pulp is thought to have excellent possibilities as a carbohydrate feed.

The process of manufacture of edible-canna starch is described.

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